WATER WORKS & SEWERAGE

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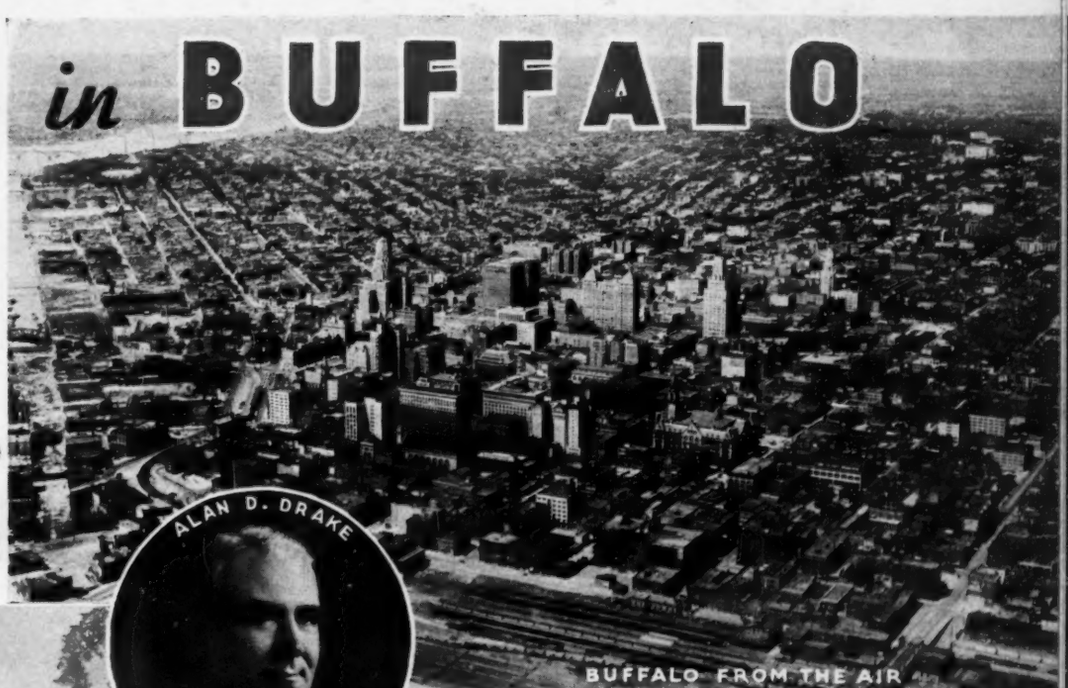
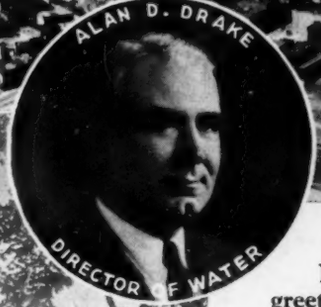
EDITOR

MAY, 1937
VOLUME 84. No. 5

See You in BUFFALO at the A.W.W.A. CONVENTION



BUFFALO FROM THE AIR



BUFFALO CITY HALL

Buffalo, Queen City of the Lakes, extends a hearty greeting and a warm hand of friendship to the members of the American Water Works Association.

A richly historic city, still preserving original sites and relics of its earlier and more turbulent days, Buffalo is a beautiful city, too, proud of its proximity to the great Dominion of Canada and the awe-inspiring grandeur of Niagara Falls.

Buffalo is the second largest railroad center in America and one of the ten largest ports in the world. Its industries are widely diversified, with the largest single hydro-electric development in the United States at its door, grain elevators piercing the skyline, airplane, rayon, rubber factories, and steel mills. And, too, Buffalo may well be proud of its excellent water supply system and its efficient water department which serves this great industrial and domestic population.

PITTSBURGH EQUITABLE METER CO.
MERCO NORDSTROM VALVE CO.
MAIN OFFICES PITTSBURGH, PA.

NEW YORK	LOS ANGELES	TULSA	HOUSTON	MEMPHIS	BUFFALO
COLUMBIA	KANSAS CITY	CHICAGO	PHILADELPHIA	ATLANTA	OAKLAND

PITTSBURGH WATER METERS

Installation of cast iron pipe for District of Columbia Sewage Disposal Plant

The reasons why cast iron pipe is so largely used for sewage disposal plants are equally forceful arguments for the use of cast iron pipe for sanitary sewers that enter such plants. Cast iron sewers are infiltration-proof because they have permanently tight joints. The material itself is impermeable in addition to possessing great compressive strength and effective resistance to corrosion. We carry large stocks of pipe and fittings at 15 shipping points throughout the United States.

UNITED STATES PIPE AND FOUNDRY COMPANY
BURLINGTON NEW JERSEY

Foundries and Sales Offices throughout the United States

U. S. CAST IRON PIPE

for sewers and sewage treatment plants

The AIRVEYOR

THE Pneumatic Conveying System

FOR -

Lime - Soda ash -
Bauxite - Borax -
Alum - Ferric Sulphate

ILLUSTRATED on this page, a few Airveyor installations handling lime, soda ash, alum, ferric sulphate, the most efficient and economical system for unloading and conveying your granular materials. This system offers many advantages and economies, some of which are:

- Savings by purchasing in bulk
- Minimum handling and storage cost
- One man operation
- Simple and inexpensive storage facilities; the Airveyor will recover from all types, open stock piles or enclosed steel bins
- First cost sufficiently low to warrant investment
- Maintenance requirements are negligible
- Simple plant layout; installation can be made without interrupting present operation
- Absolute cleanliness.

Can't we interest you in this modern method of conveying? Fill in the coupon below and we will gladly send you detailed information.

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FULLER COMPANY
CATASAUQUA, PA.
Please send me literature on the Airveyor.

_____

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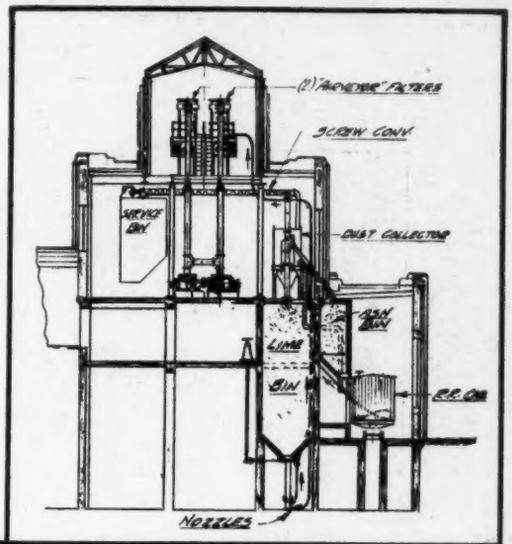
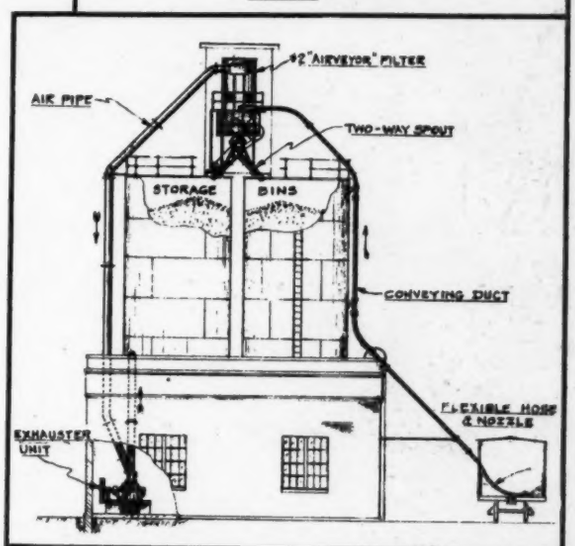
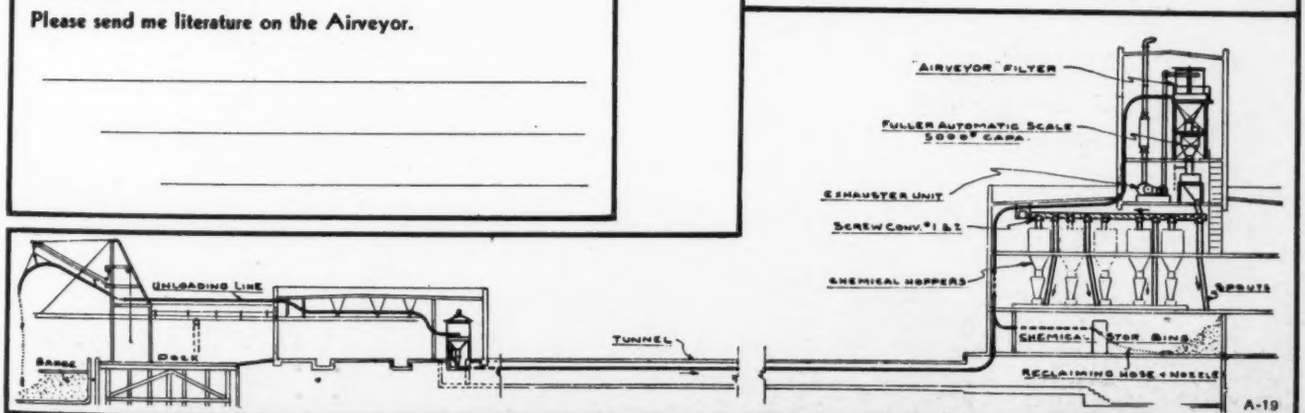
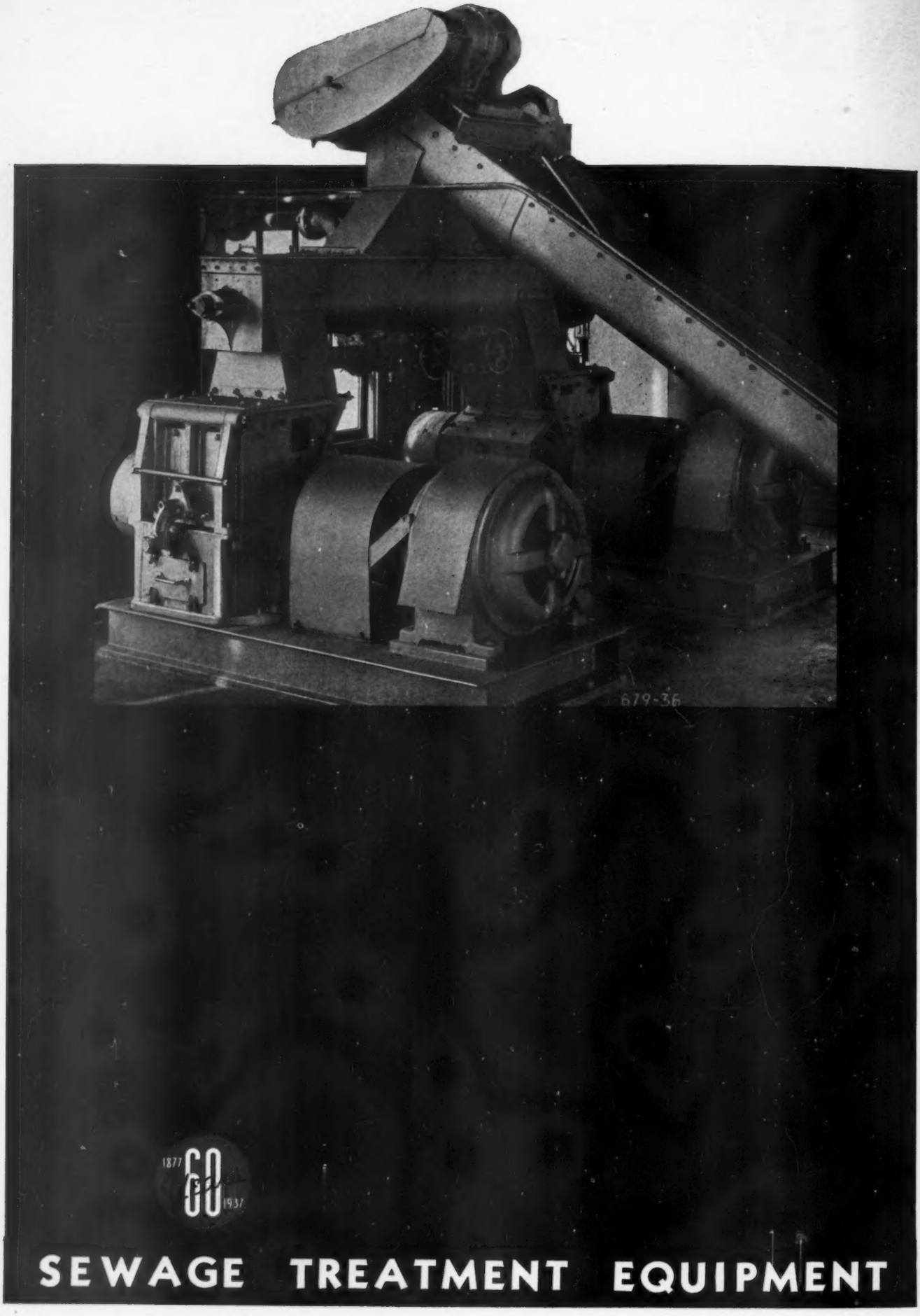






FULLER-KINYON, FLUXO, AND AIRVEYOR CONVEYING SYSTEMS · · · ROTARY FEEDERS AND DISCHARGE GATES
ROTARY AIR COMPRESSORS AND VACUUM PUMPS · · · AUTOMATIC BATCH WEIGHERS · · · BIN SIGNALS

WATER WORKS AND SEWERAGE, May, 1937, Volume 84, Number 5. Published monthly at 400 West Madison Street, Chicago, Ill., by the Gillette Publishing Company. Per copy, 25c. Subscription rate, $2.00 per year; Canadian and Foreign, $3.00 per year. Copyright, 1937. Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under the Act of March 3, 1879.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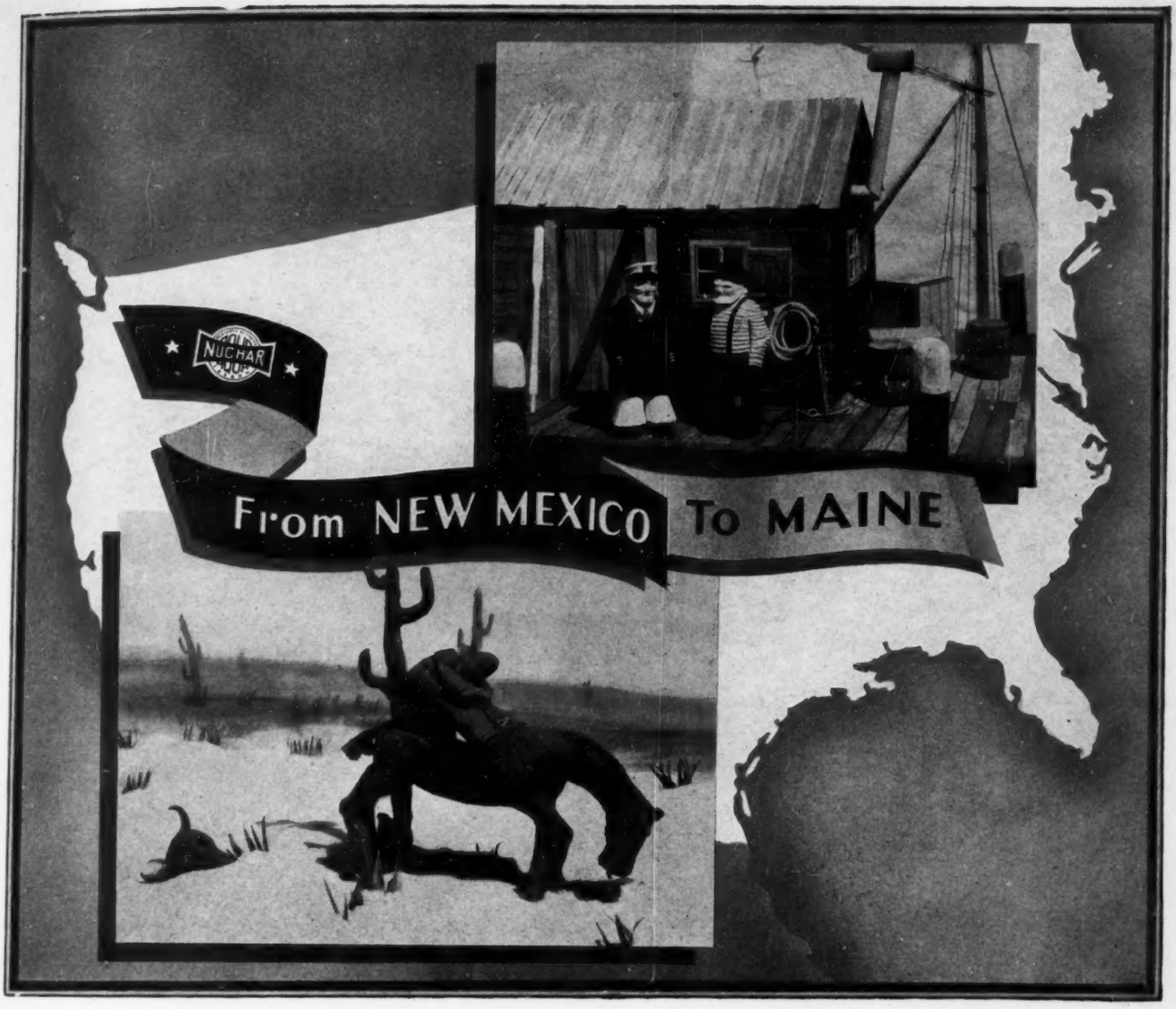
SEWAGE TREATMENT EQUIPMENT



Modeled by E. C. Arink

NUCHAR INSURES PALATABLE DRINKING WATER

"The availability of a cheap powdered activated carbon opens wide the field for experimentation with its use in combating tastes and odors from water supplies in existing water purification plants."

Malcom Pirnie, Consulting Engineer, New York City, May, 1931, Annual Meeting American Water Works Ass'n, Pittsburgh, Penna.

● How accurate was this forecast is evidenced by the events of the past six years.

How widespread has been its application may be gained from our records indicating that AQUA NUCHAR has been furnished to over 1,000 water plants in 47 of the 48 States in the United States, and shipments have been made throughout the world.

Great strides have been made in its application for taste and odor removal and with few exceptions it has successfully combated tastes and odors of most every origin.

In a recent survey made of 137 Plants using AQUA NUCHAR we were advised that approximately 52% are applying carbon continously.

There has been a definite trend towards the furnishing of a palatable drinking water.

Constant surveys made indicate that palatable drinking water through the use of Activated Carbon has been furnished at a cost of less than 5c per person, per annum.

"Make your plans now to attend the 57th Annual Convention of the American Water Works Association, to be held June 7-11, 1937, at the Hotel Statler, Buffalo, N. Y."

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DIVISION WEST VIRGINIA PULP AND PAPER COMPANY

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Specializing for years in the design and manufacture of equipment for the Water Works Field, Western Gas Division offers a comprehensive line of products to meet ordinary needs, has the engineering background to efficiently solve extra-ordinary problems.

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Tarmac Road Tars · Treated Timber
Waterproofing · Waterworks Gate Valves
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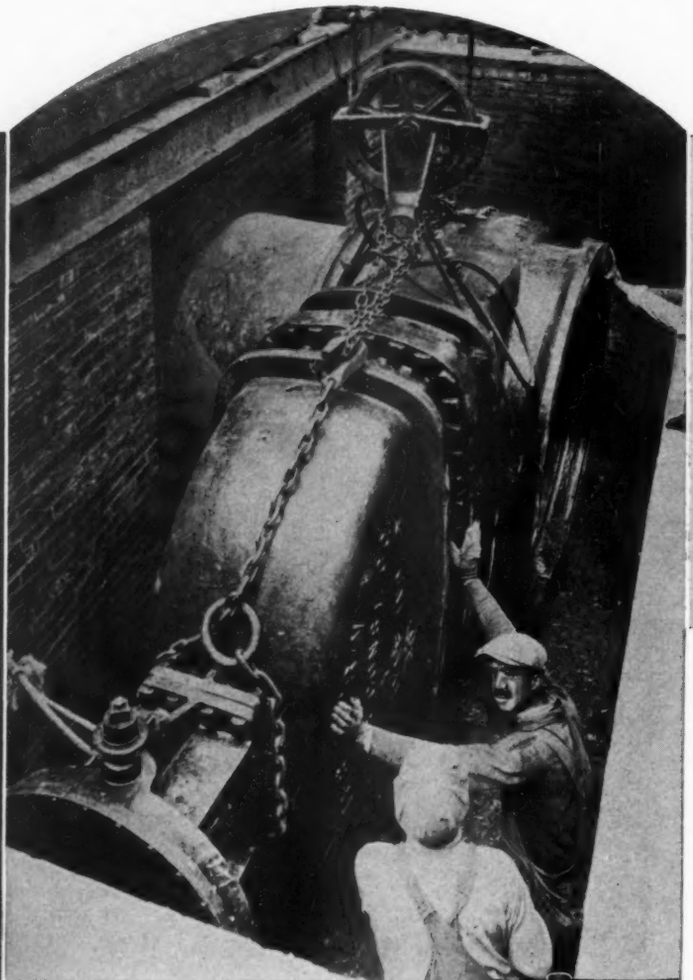
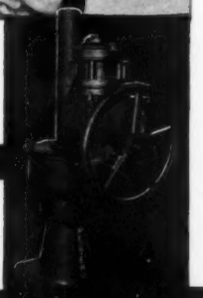
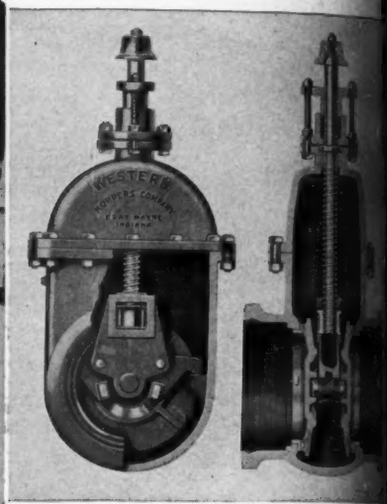


Installing a 60" Western Standard gate valve for the Cincinnati Water Works, Cincinnati, Ohio. Due to the design, Western Standard Gate valves may be installed and operated in any position. The advantages of this latitude are apparent in the picture.



Motor (universal electric) operated Floor Stand for rising stem sluice gate . . . one of the many types made by Western Gas.



The Standard Type A Waterworks Gate Valve operates with a positive dual-movement, which eliminates many common difficulties. In the first stage of valve opening, the symetrically dished double discs move toward each other, and away from their respective seats. In the second stage, the discs move upward, out of the waterway. In closing the process is reversed. This eliminates rubbing and wear on faces. Discs are free to rotate, and are flanged to roll on tracks. Thus valve can be operated in any position without the addition of the usual track rollers and scrapers.

KOPPERS COMPANY
Western Gas Division . . . Fort Wayne, Indiana

STEMS *for Valves and Gates . . . . Forged or Cast*

BRONZE STEM FORGING INSURANCE

To insure perfect forgings, continuous and painstaking metallurgical and thermal control under one single responsibility is essential. Otherwise forging may be done above or below the extremely narrow critical temperature range, and result in laminations, seams or checks—often invisible, but constituting a definite hazard. Bartlett Hayward Division insures perfection by carrying on every operation—from alloying and billet manufacture, through casting or forging to final rough-turned or completely machined stems—under one roof, and under unified supervision. Results are apparent wherever Bartlett Hayward valve stems are in use. You'll be pleased with the promptness of quotations and deliveries.

Stems, 4" dia. x 22'9" long. B-H Forged Manganese Bronze—K-B 30 Alloy.

Report of Physical Properties

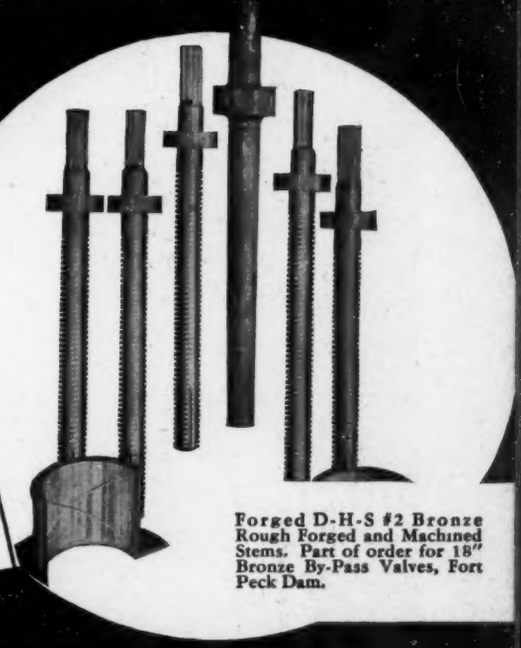
Material....D-H-S #2 Bronze
U.T.S...115,000 #/sq. in.
Yld. Pt.....90,000
El. Limit.....55,000
Elong. 2".....12%
For High Pressure, Rigorous Service

Report of Physical Properties

Material....K-B 20 Alloy
U.T.S....80,000 #/sq. in.
Yld. Pt.....40,000
Elong. 2".....20%
For High Grade Manganese Bronze Applications.

Report of Physical Properties

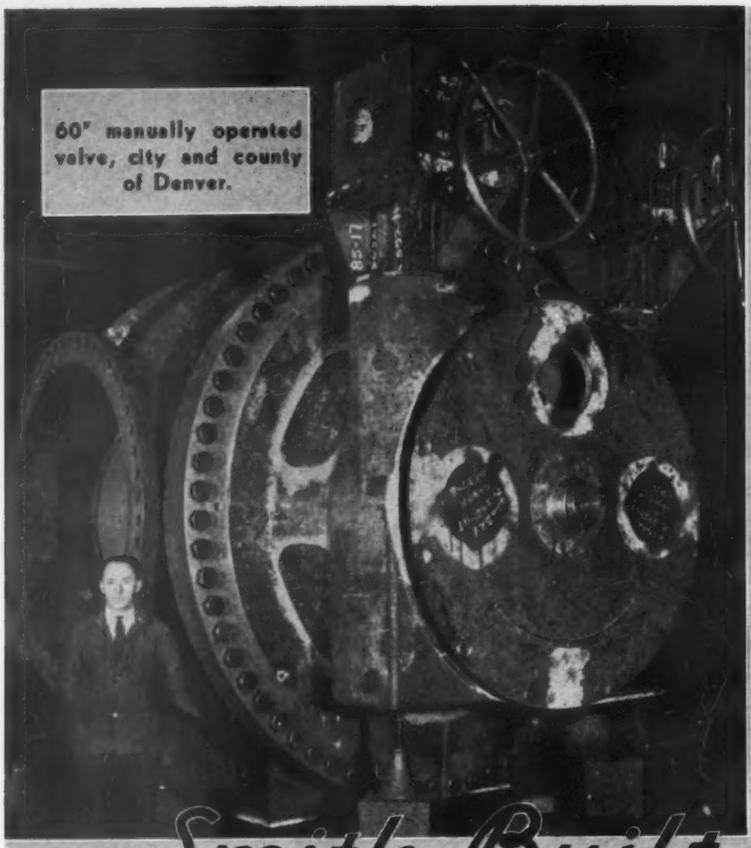
Material....K-B 21 Alloy
U.T.S....65,000 #/sq. in.
Elong. 2".....25%
For Ductile Manganese Bronze Stem Applications.



Forged D-H-S #2 Bronze Rough Forged and Machined Stems. Part of order for 18" Bronze By-Pass Valves, Fort Peck Dam.

KOPPERS COMPANY

Bartlett Hayward Division . . . . Baltimore, Md.



60" manually operated valve, city and county of Denver.

Fluid CONTROL

The Cone Type of Valve featured herewith, the widely used ROTOVALVE, is designed with many inherent advantages and has a definite place in the field of fluid control. Built in standard sizes from 6" to 48" and in special sizes of 54" and larger, with hydraulic, motor or manual operation.

Rotovalves are neat, compact, with monel metal seat rings and 3-bearing mounting of plug. Full Alemite lubrication. All working parts can be removed with pressure on valve.

APPLICATIONS: Automatic Check—Pressure Regulating—Pressure Relief—Electric Control Altitude—Hydraulic Stop—Manual Stop—Float and Blow-Off—Free Discharge—Synchronous Relief.

Smith Built ROTOVALVES

48" automatic check valve, (partially assembled) city of Milwaukee.

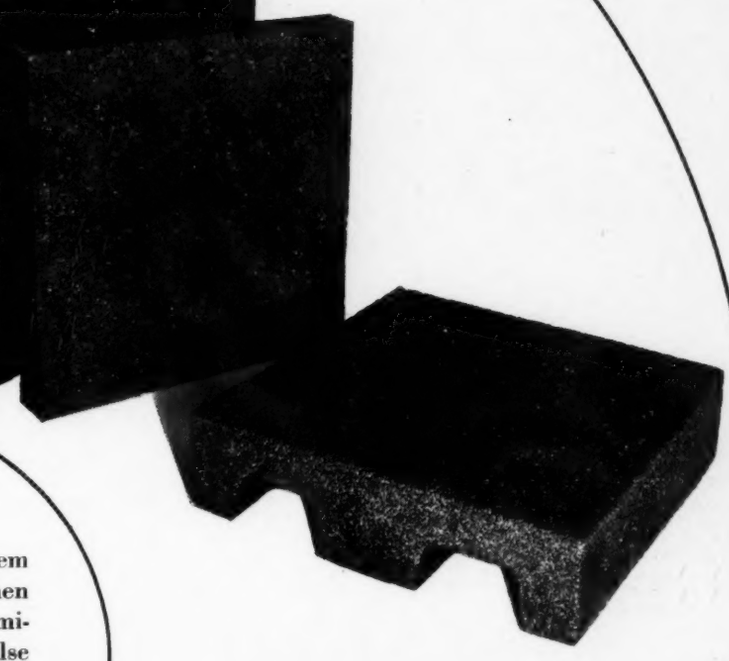
S. MORGAN SMITH COMPANY • YORK, PENNA.

ALOXITE

REG. U. S. PAT. OFF.

BRAND POROUS MEDIUMS

in the water treatment field!



1 *The new RSF Porous Plate Underdrain* system with channels for rapid sand filters. Then there are plain porous underdrain plates of similar special coarse structure for use as a false bottom in filters of either pressure or gravity type.

2 *Diffuser Plates and Tubes* for aeration of water and mixing of chemicals. Proved by experience in many cities as an economical and effective method of accomplishing such objectives.

3 *Diffuser Tubes* for recarbonation chambers. The most efficient way to introduce clean CO_2 into water. Practiced successfully at Beverly Hills, California and elsewhere.

4 *Filter Tubes* for direct filtration of industrial water supply.

Write for technical literature and submit your water treatment problem to our Sanitary and Filtration Department.

(Carborundum and Aloxite are registered trade-marks of The Carborundum Co.)

THE CARBORUNDUM COMPANY

REG. U. S. PAT. OFF.

Niagara Falls, N. Y.

Sales Offices and Warehouses in New York, Chicago, Boston, Philadelphia, Cleveland, Detroit, Cincinnati, Pittsburgh, Grand Rapids

COLUMBIA

Another series of races will soon be sailed for the America's Cup. In the long history for the defense of this premier yachting trophy there have been two yachts named Columbia. Back in 1871 the center-board schooner Columbia took two races from the British challenger Livonia. She won because she was the faster boat in the prevailing weather conditions.

Schooner Yacht Columbia off Sandy Hook, October, 1871

SUCCESS

in business as in yachting depends in large measure on the selection of materials that best meet existing conditions. THE COLUMBIA ALKALI CORPORATION has been signally successful in supplying products developed, packaged and serviced to meet customers' individual requirements and convenience.

Send for new folder on COLUMBIA Liquid Chlorine

COLUMBIA LIQUID CHLORINE

(In Single and Multiple Unit Tank Cars, 100 and 150 lb. Cylinders.)

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CAUSTIC SODA
SODIUM BICARBONATE
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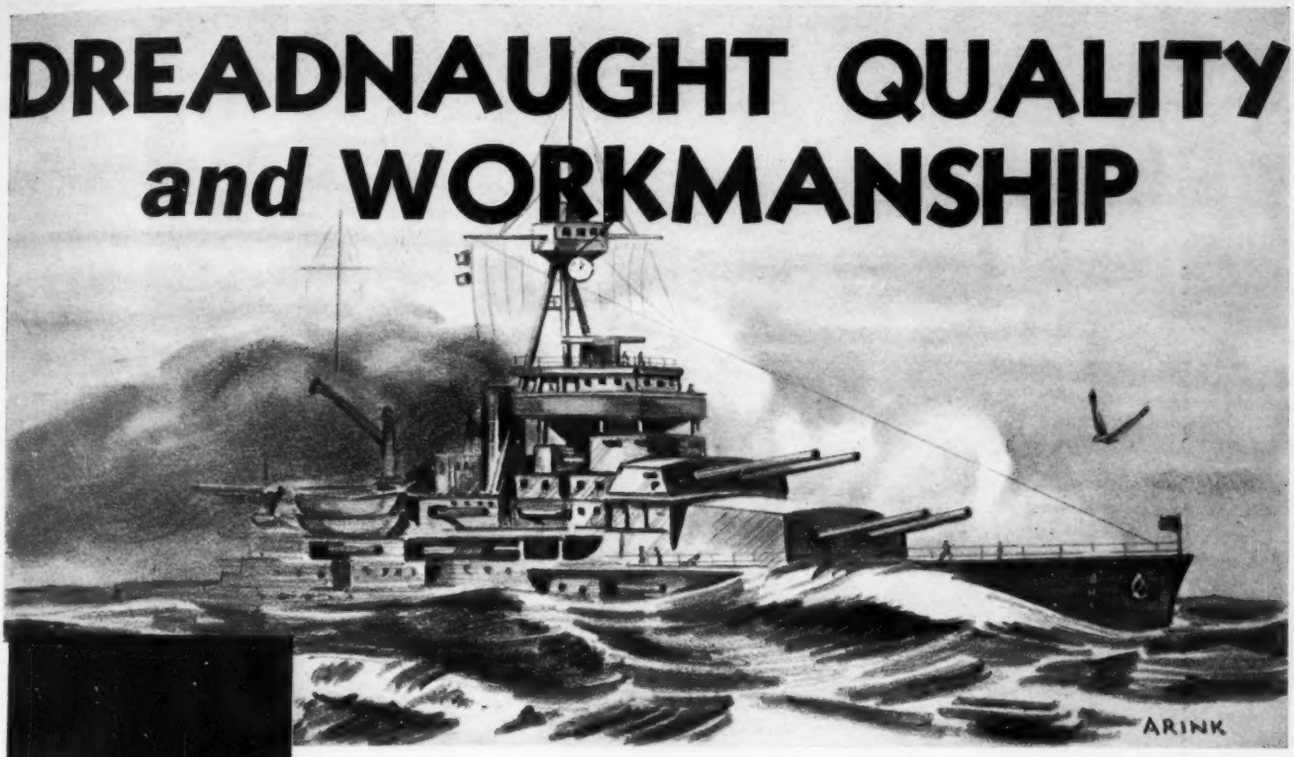
DREADNAUGHT QUALITY *and* WORKMANSHIP

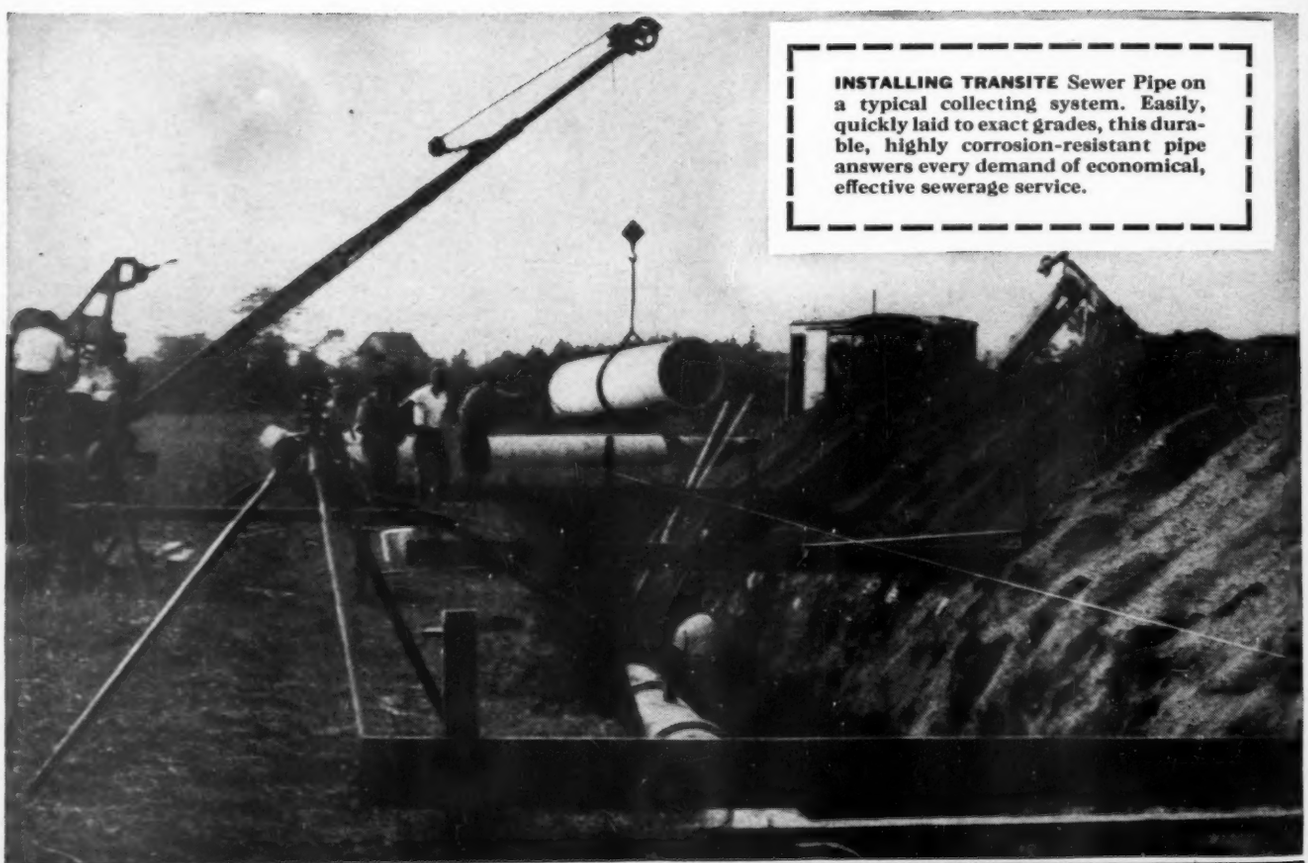


in every ● VALVE & HYDRANT

A leak will sink a battleship—It will also sink your profits through excessive pumping costs, maintenance expense and interrupted service — Guard against these enemies by using M & H Fire Hydrants and Valves. They are designed and built for your protection and are dependable in normal service as well as all emergencies.

M & H waterworks products are thoroughly in accord with and exceed A.W.W.A. specifications and furthermore, they are approved and listed by the National Board of Fire Underwriters as well as Associated Factory Mutual Fire Insurance Companies for Fire Protection Installations.

-AND NOW TRANSITE SEWER



INSTALLING TRANSITE Sewer Pipe on a typical collecting system. Easily, quickly laid to exact grades, this durable, highly corrosion-resistant pipe answers every demand of economical, effective sewerage service.

Johns-Manville TRANSITE

AFTER THREE YEARS' TESTING

PIPE—

Accelerated laboratory tests . . . 3 years of field service under a wide range of severe conditions . . . have already proved that in this newly announced asbestos-cement product, Johns-Manville offers a sewage carrier whose advantages assure lower installation, operating and maintenance costs

BY combining in *one* material *all* the requirements demanded by effective sewerage service, Transite Sewer Pipe immediately takes its place as a new and important factor in the economical, efficient disposal of sewage.

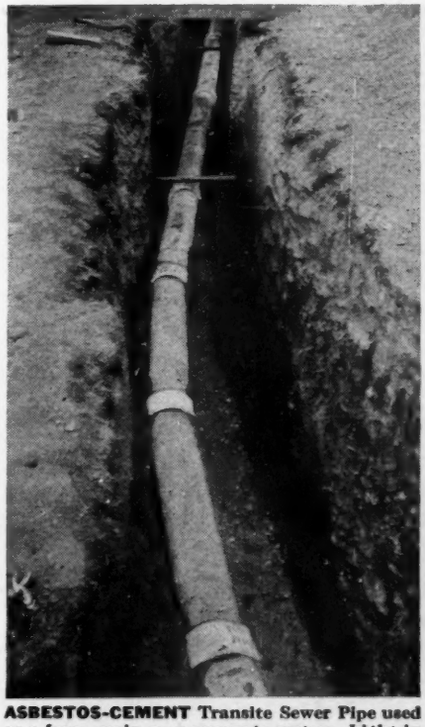
Like Transite Pressure Pipe, this newly announced product is formed of asbestos and cement into a dense, smooth-surfaced, homogeneous structure. A composition with unusual resistance to corrosion and a time-established record for durability.

Great in strength, Transite Sewer Pipe is light in weight . . . more economical to transport and handle. Moreover, Transite Sewer Pipe is furnished in 13-foot sections. Long lengths that considerably reduce the number of joints used . . . and consequently, the cost of installation.

On collecting systems, particularly, these long lengths make installations of Transite Pipe to exact grades a quicker, cheaper and more accurate job.

A careful consideration of these facts leads to one conclusion . . . now there is a modern sewer pipe, for both force and collection mains, that offers all the advantages necessary to economical installation and continued effectiveness in service.

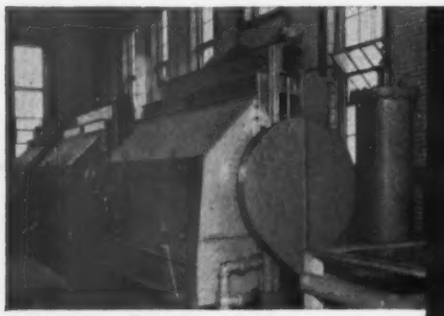
The manufacturing, installation and service story in complete detail will undoubtedly interest you. For full information on Transite Sewer Pipe, write Johns-Manville, 22 E. 40th Street, New York City.



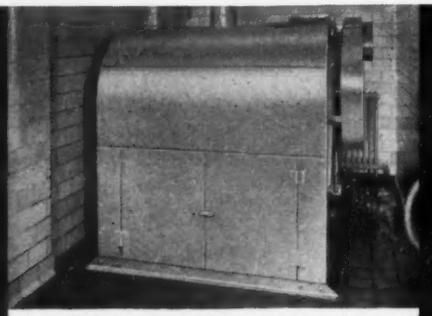
ASBESTOS-CEMENT Transite Sewer Pipe used as a force-main on a sewerage system. Light in weight and long in length, Transite Sewer Pipe can be installed with notable speed and economy. Here, Simplex Couplings are used to assure bottle-tight joints.

SEWER PIPE AN ASBESTOS PRODUCT

HOW TO HANDLE IT IF *IT* IS SEWAGE, TRADE WASTES OR WATER TREATMENT

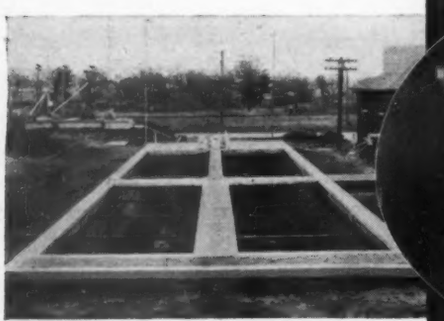


Rex Traveling Water Screens for screening of intake water in waterworks and power plants.

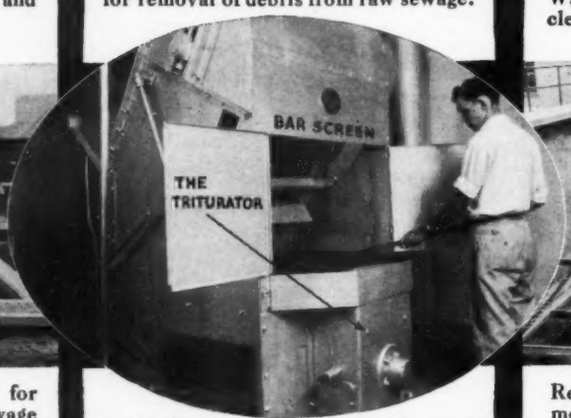


Rex Mechanically Cleaned Bar Screen for removal of debris from raw sewage.

Rex V-Bucket Grit Collectors and Washer for collection of detritus and cleaning it prior to disposal.



Rex Conveyor Sludge Collectors for primary and secondary tanks in sewage disposal plants.

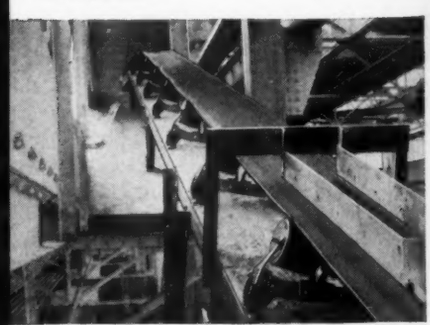


The Rex Triturator thoroughly disintegrates sewage screenings so that they can be returned to the sewage and handled as primary tank sludge.

Rex Conveyor Sludge Collectors for removing sludge and silt in water treatment plants.

Rex Plunger Sludge Pumps, single and double cylinder models for handling sludge of all types.

Rex Tow-Bro Sludge Remover, an advanced type of sludge remover for secondary tanks, either round or rectangular.



Rex Belt Conveyors and Elevators for handling screenings, dried sludge, grit and chemicals.

When designing a new plant or modernizing an old one investigate Rex sanitation equipment. Specialized catalogs are available at our nearest branch office or from our Sanitation Equipment Division, 1610 W. Bruce St., Milwaukee, Wisconsin.

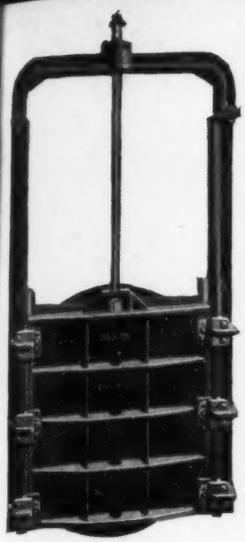
REX

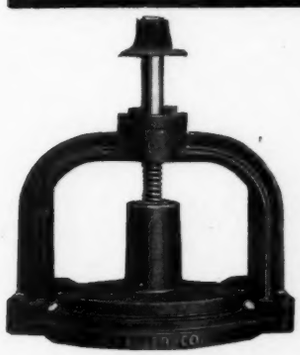
CHAIN BELT COMPANY of MILWAUKEE

Sanitation Equipment

MUELLER COLUMBIAN LINE OF

SLUICE GATES
FLOOR STANDS
GATE HOISTS
SHEAR GATES
FLAP VALVES
MUD VALVES





Mueller-Columbian Water Control Equipment is noted for its enduring strength and unfailing performance because of the simplified design and perfected manufacturing methods. Each piece of equipment is carefully made to exacting standards and checked and tested at the factory to insure easy operation and trouble-free operation when installed.

Not only does Mueller-Columbian fill regular requirements, but an engineering department is at your disposal to assist in the solution of any special problem and to recommend and provide the RIGHT equipment to do the job. Get in touch with Mueller-Columbian on your next water control project. Quotations and detailed information will be gladly furnished upon request.

Mueller Co., Chatta., Tenn.

Mueller Co., Dept. ABCD

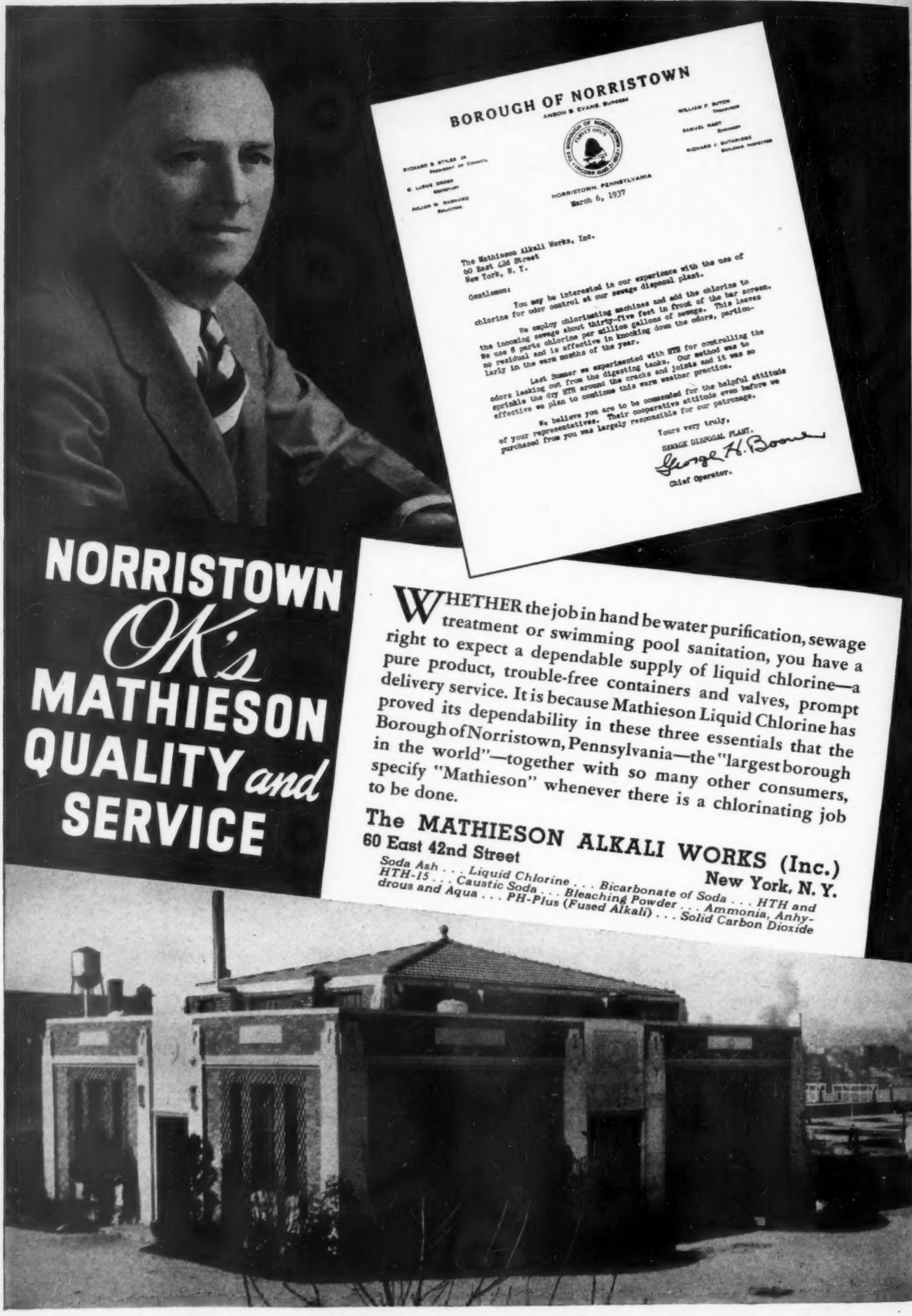
Chatta., Tenn

Kindly send me your new A-300 Catalog o
Water Control Equipment.

Name .....

Address .....

City .....


BOROUGH OF NORRISTOWN
ANSON B. EVANS, BURGESS
NORRISTOWN, PENNSYLVANIA
March 6, 1937
The Mathieson Alkali Works, Inc.
60 East 42d Street
New York, N. Y.
Gentlemen:
You may be interested in our experience with the use of chlorine for odor control at our sewage disposal plant.
We employ chlorinating machines and add the chlorine to the incoming sewage about thirty-five feet in front of the bar screen. We use 8 parts chlorine per million gallons of sewage. This leaves no residual and is effective in knocking down the odors, particularly in the warm months of the year.
Last Summer we experimented with HTH for controlling the odors leaking out from the digesting tanks. Our method was to sprinkle the dry HTH around the cracks and joints and it was so effective we plan to continue this warm weather practice.
We believe you are to be commended for the helpful attitude of your representatives. Their cooperative attitude even before we purchased from you was largely responsible for our patronage.
Yours very truly,
SEWAGE DISPOSAL PLANT.
George H. Bowers
Chief Operator.
NORRISTOWN OK's MATHIESON QUALITY and SERVICE
WHETHER the job in hand be water purification, sewage treatment or swimming pool sanitation, you have a right to expect a dependable supply of liquid chlorine—a pure product, trouble-free containers and valves, prompt delivery service. It is because Mathieson Liquid Chlorine has proved its dependability in these three essentials that the Borough of Norristown, Pennsylvania—the "largest borough in the world"—together with so many other consumers, specify "Mathieson" whenever there is a chlorinating job to be done.
The MATHIESON ALKALI WORKS (Inc.)
60 East 42nd Street
New York, N. Y.
Soda Ash . . . Liquid Chlorine . . . Bicarbonate of Soda . . . HTH and HTH-15 . . . Caustic Soda . . . Bleaching Powder . . . Ammonia, Anhydrous and Aqua . . . PH-Plus (Fused Alkali) . . . Solid Carbon Dioxide

Here's "Something to Show" for relief funds!

Typical section of Atlanta's new concrete pipe sewers. A well-engineered and well-constructed job with excellent alignments and uniform gradients throughout. Pipe is carefully bedded and back-filled; joints made with portland cement mortar to minimize infiltration. Work was executed by Works Progress Administration of Georgia, District No. 5, in cooperation with Clarke Donaldson, chief of construction and W. A. Hansell, assistant chief of construction in charge of sewers for City of Atlanta.

34 MILES OF ENDURING CONCRETE PIPE ADDED TO ATLANTA'S SANITARY AND STORM SEWER SYSTEM

Atlanta's 7-million-dollar program, including new sewage treatment plants, new sanitary and storm sewers, extensions and outlets, is now nearing completion. 34 miles of concrete pipe ranging in size from 8 in. to 102 in. has already been placed under various WPA and FERA projects.

Atlanta joins the Sanitary District of Chicago, Louisville, Detroit, Minneapolis and many other cities which rely on concrete for their sewers. Concrete pipe, like monolithic concrete, has proved its merits for a wide range of sewer types, sizes and conditions. It is strong and durable. Minimizes infiltration and leakage. Is moderate in cost and serves with little maintenance.

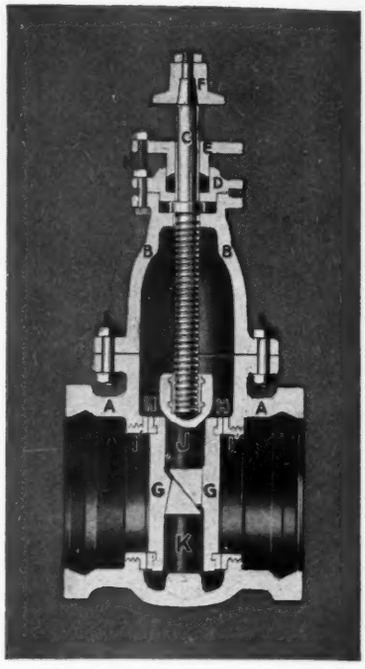
Whether your sewers are 12 ft. in diameter or a few inches, build them of concrete and be sure!

Write for pipe bulletins on jacking concrete pipe, building pipe sewers in open cut, pipe in tunnel, subaqueous methods, and standard specifications of the A.S.T.M.

PORTLAND CEMENT ASSOCIATION
Dept. 5-29, 33 W. Grand Ave., Chicago, Ill.
Please send me concrete pipe bulletins 9 to 14.

*Name*_____
*Position*_____
*Address*_____
*City*_____ *State*_____

71 YEARS of WATER WORKS SERVICE



This cutaway illustrates the basic design of every Ludlow valve. Note the sturdy construction — absence of complicated working parts.

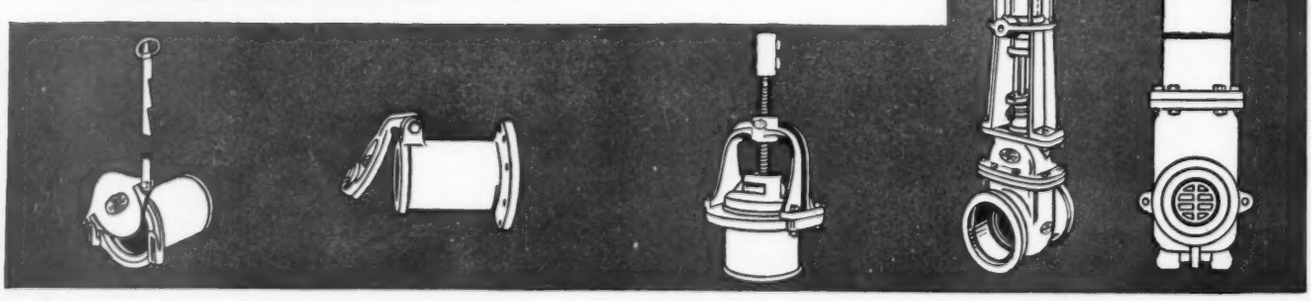
On the occasion of the 1937 American Water Works Association Annual Meeting, The Ludlow Valve Mfg. Company extends a cordial greeting to its thousands of friends.

Ever since Ludlow originated the double disc gate valve many years ago, it has been constantly improving materials, methods and equipment for the better service of the water works industry. Its accumulated experience and the technical knowledge of Ludlow engineers are freely offered to Association members toward the solution of their problems.

Ludlow has cooperated closely with the A. W. W. A. since the Association was formed 57 years ago. It pledges itself once again to continue this friendly and mutually beneficial relationship.

All Ludlow water works valves conform rigidly to A. W. W. A. specifications.

THE LUDLOW VALVE MFG. CO.
TROY, N. Y.



EBG MAKES A CLEAN GETAWAY...WASHED AND DRIED WITH STEAM...*When a cylinder is returned to EBG it is inverted on a special machine and the inside is scoured clean as a surgeon's instrument. It is then steamed... air-dried... inspected with a special light. The valve is reconditioned, tested for perfect operation. From top-to-bottom, inside and out, EBG containers are subjected to a stern system of cleaning, inspecting and reconditioning. This is the way we make sure that EBG Liquid Chlorine is pure and makes a "clean getaway" from our plant to yours.*

•

ELECTRO BLEACHING GAS COMPANY
Main Office: 60 East 42nd Street, New York, N. Y.
Plant: Niagara Falls, N. Y.

EBG Liquid Chlorine
FIRST IN THE COUNTRY

RUN THIS TEST ON PETRI DISHES

in Your Own Laboratory

PERHAPS, in your culture work, you have noticed but little visible difference in Petri Dishes. You may have even thought they were all alike. Sooner or later, however, the difference becomes apparent, frequently at a time when it is most annoying and inconvenient.

Here is a test you can run in your own laboratory, if you wish. It will prove conclusively that while there is small difference in cost there is a vast difference in the quality of Petri Dishes.

Take several Petri Dishes—one of them "PYREX" Brand Ware. Subject them to from 15 pounds to 50 pounds steam pressure in your sterilizer for 120 hours or longer. At the end of the test, remove and inspect them, and determine the loss in weight.

The "PYREX" dish will have lost less weight. It will be clear, transparent, unclouded, permitting unhampered examination of the growing culture.

The comparatively small loss in weight of "PYREX" dishes, even under these accelerated test conditions, indicates definitely that the pH of the culture will not be appreciably changed by glass solubility.

This test will demonstrate to you, once and for all, the ability of a "PYREX" Petri Dish to withstand repeated sterilization, frequent washings—hard usage. Its exclusive beaded edge gives it unparalleled mechanical strength. You already know of its superior heat-resistant qualities.

T.M. REG. PYREX U.S. PAT. OFF.

Run this destructive, yet constructive test. Convince yourself that it pays to specify "PYREX" Brand Petri Dishes.

Only 38c per pair; substantially lower prices in quantity purchases.

"PYREX" is a registered trade-mark and indicates manufacture by

CORNING GLASS WORKS
Corning, New York

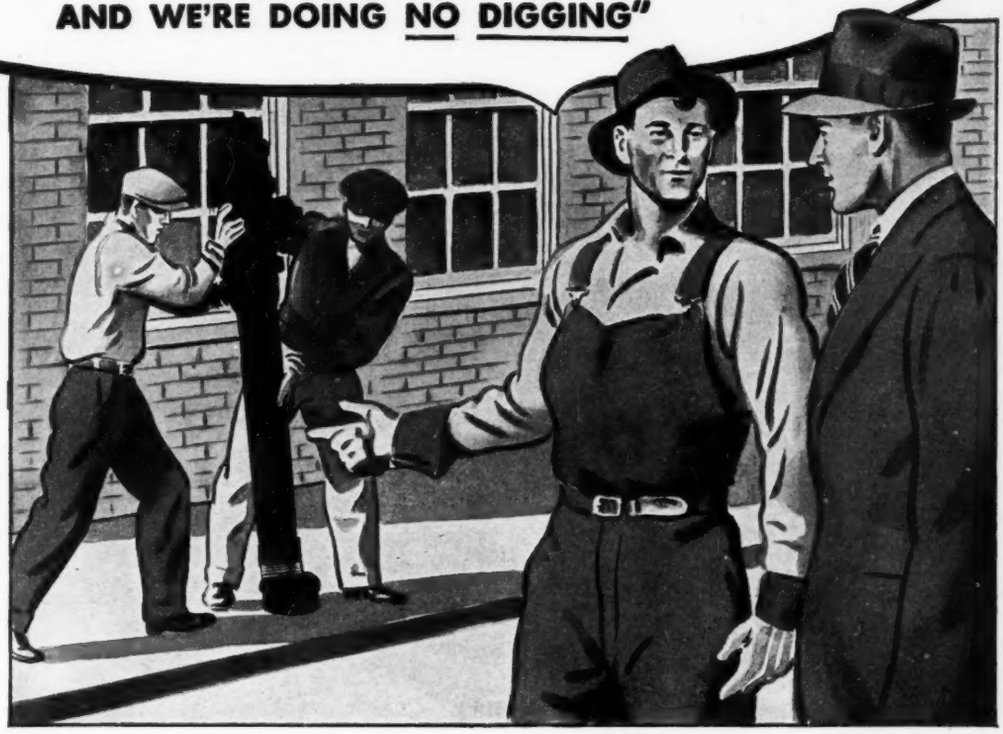
Pyrex BRAND

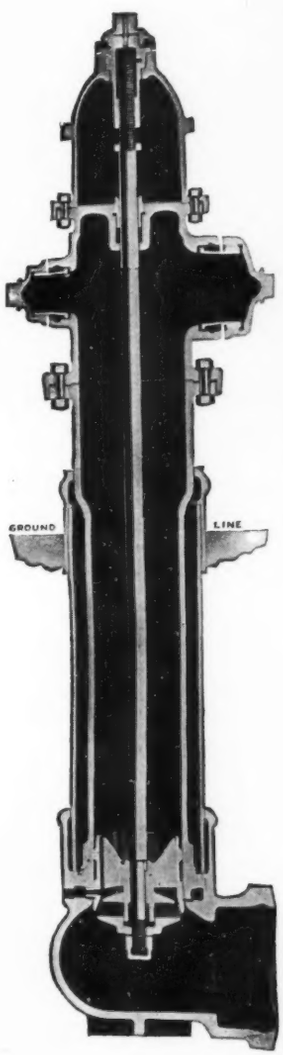
LABORATORY GLASSWARE

"WE'RE REPLACING 67-YEAR-OLD HYDRANTS WITH

Mathews Modernized Barrels

AND WE'RE DOING NO DIGGING"





THIS superintendent has a real money-saver. He's getting new hydrants practically without installation cost. Steamer nozzles, revolving head, and all new working parts. His original Mathews Hydrants gave 67 years of dependable service and he'll get even more from these. One more reason for specifying Mathews. Modernized Mathews Barrels completely renew every working part of a Mathews Hydrant. They cost less to buy than complete hydrants. You can set them in 15 minutes without digging. Write for prices.

• • •

The elbow at the bottom of the Mathews Hydrant is threaded. It lets you unscrew the entire barrel and lift it out through the loose protection case. No digging necessary for modernization, accident repair, occasional overhaul and grade changes.

Mathews Hydrants

BUILT FOR EMERGENCIES

R. D. WOOD CO.

400 Chestnut St., Philadelphia, Pa.

manufacturers of SAND-SPUN PIPE which is centrifugally cast in sand molds, and R. D. Wood heavy-duty gate valves for water works.

THERE IS MONEY! IN YOUR SLUDGE

Machines made in four sizes—either belt, gasoline engine or electric drive.

USING THE ROYER DISINTEGRATOR

A Royer Disintegrator Will Pay for Itself

The Royer Sludge Disintegrator will rapidly and economically shred sludge containing from 30 to 60 per cent moisture into fine particles at a cost of thirty cents or less per cubic yard. The smallest size disintegrator will shred 2 cubic yards per hour using a ¾ H. P. motor. Operating costs are therefore very low, as also are maintenance and repair costs.

Numerous instances can be cited from the records showing that purchasers of ground sludge find the material valuable for lawns or gardens. As one superintendent of a large sewage plant expressed it, "They come back for more."

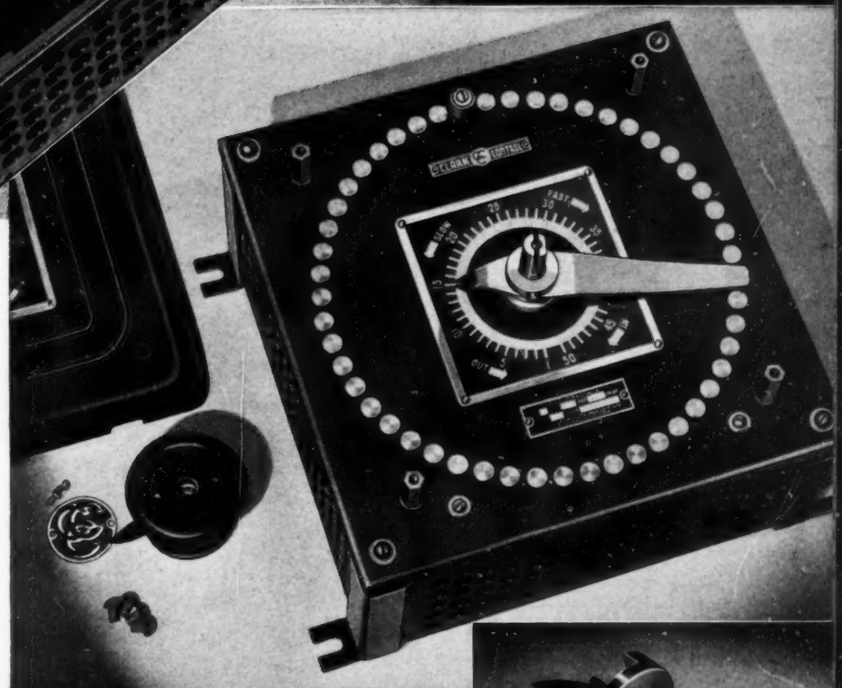
In many instances the cheap supply of compost for municipal parks, lawns and gardens will soon pay for the disintegrator.

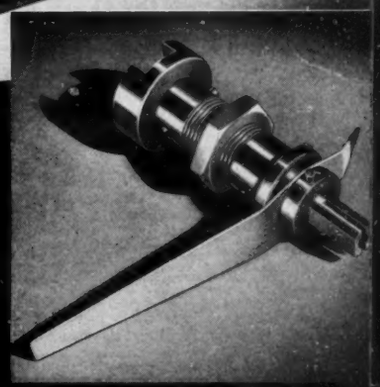
Let us send you details of the machine and interesting information on the value of Disintegrated sludge as a fertilizing compost.

ROYER FOUNDRY & MACHINE CO.

158 Pringle St. — Kingston, Pa.

C. G. WIGLEY, Sole Rep.
3108 Atlantic Ave., Atlantic City, N. J.





TRULY, the Clark Rheostat has been given a new personality. . . . *Handsome*, some have exclaimed. Note the newly conceived steel cover—streamlined, you might say. Rich black with black Bakelite handle and contrasting red indicator easily read . . . *Rugged?* Look at that husky shaft—at the diameter of it. Notice the long bearing built to "take it". Strength and long life? Decidedly . . . *Accessible.* Individual resistor grids are easily replaced and other repairs made. . . . All dressed up is this Clark Rheostat—and destined, we believe, to go somewhere. How about making a visit to your plant very soon?

THE CLARK CONTROLLER COMPANY

1146 EAST 152nd STREET CLEVELAND, OHIO

ASSURES BETTER CONCRETE with

POZZOLITH

South Mountain Reservoir at Allentown, Pa., Offers Typical Proof!

(Job illustrated above)

Engineer—MORRIS-KNOWLES, INC.—PITTSBURGH, PA.
Contractor—M. A. LONG CO.—ALLENTOWN, PA.

● You may have *tough* jobs . . . but no matter how tough they are POZZOLITH will make them EASY! For POZZOLITH assures *better* concrete . . . *better* in all the features that assure faster construction schedules, greater operating efficiency and economy, and the *finest possible standard of finished water-works and sewerage jobs!*

POZZOLITH alone can give these 6-fold advantages to *all types* of concrete mixes:

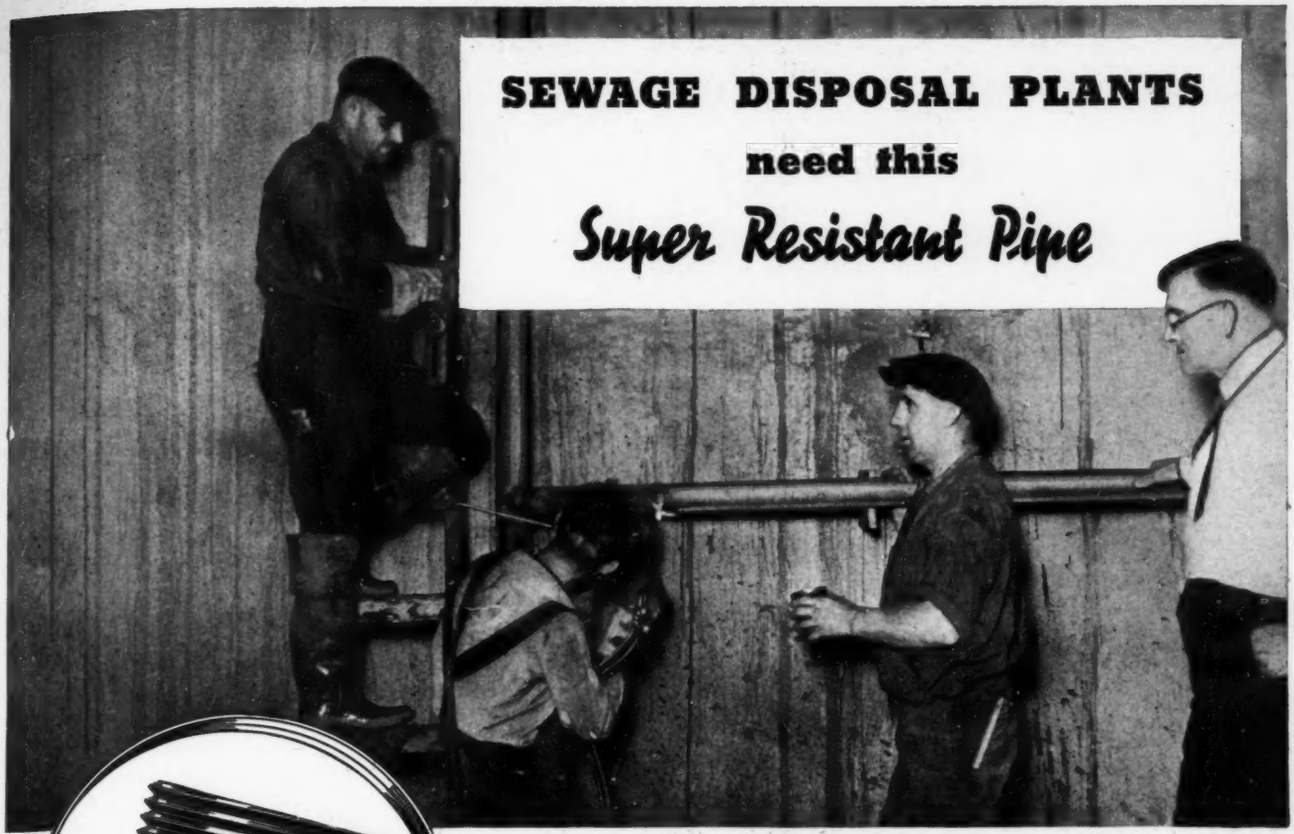
1. **Materially reduces water-cement ratio . . . *yet makes concrete more plastic, more cohesive.***
2. **Reduces time-and-labor factor in placing concrete.**
3. **Checks destructive "bleeding" and "leaching."**
4. **Assures denser, more watertight concrete.**
5. **Develops highly desirable pozzolanic activity.**
6. **Increases life of concrete.**

POZZOLITH features can be proved to you . . . simply, quickly and convincingly . . . by an experienced Master Builders man. Investigate!

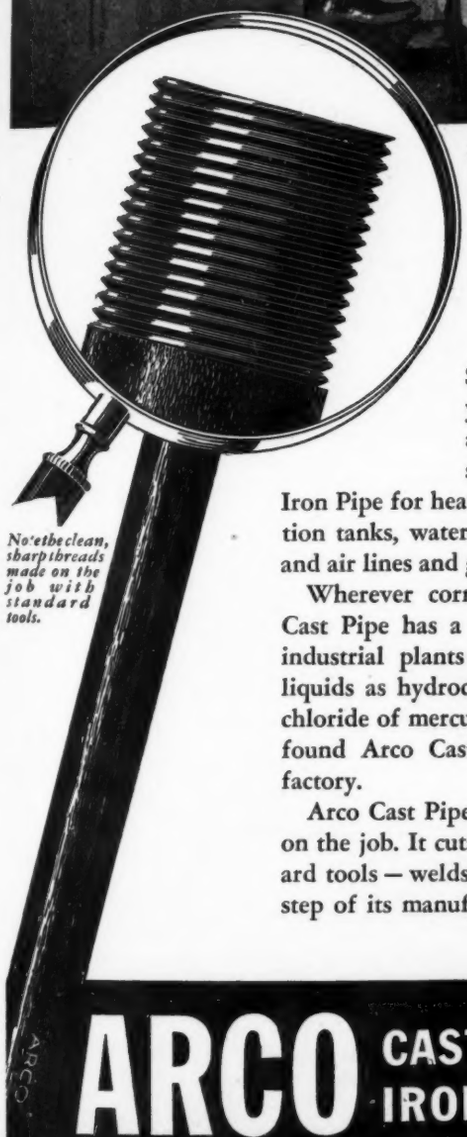
Morris-Knowles, Incorporated, says:
"We have used POZZOLITH in the concrete mix on several projects and find that it was possible to materially decrease the volume of water required to produce a placeable mix."

THE MASTER BUILDERS COMPANY · CLEVELAND, OHIO
In Canada: The Master Builders Co., Ltd., Toronto, Ontario

SEWAGE DISPOSAL PLANTS need this *Super Resistant Pipe*



(above) Welding Arco Cast Pipe in a large sewage disposal plant.



No "etbe clean, sharp threads made on the job with standard tools.

EASY TO INSTALL

...it cuts, threads and welds CLEAN with standard tools

Strike at corrosion when you install piping in sewage disposal plants. Use super-resistant Arco Cast Iron Pipe for heating coils in sludge digestion tanks, water lines in activated tanks, and air lines and gas lines to gas collectors.

Wherever corrosion is a factor, Arco Cast Pipe has a successful record. Many industrial plants piping such destructive liquids as hydrocyanic acid, ammonia, bichloride of mercury, and caustic soda have found Arco Cast Pipe thoroughly satisfactory.

Arco Cast Pipe is easy to install — right on the job. It cuts and threads with standard tools — welds smoothly. Because every step of its manufacture is carefully supervised this pipe is free from common defects. It is furnished in sizes 1½" to 12". Sizes up to 6" run 6', 12', and 18' lengths. Other lengths may be obtained on special order. Either or both ends may be plain, threaded one end or both ends, tapped bell, grooved for special couplings, or beveled for welding smoothly on the job.

Remember Arco Cast Pipe for your next sewage disposal job. Make it your standard specification for long-life efficiency.

ARCO PIPE & FITTINGS DIVISION
AMERICAN RADIATOR COMPANY
DIVISION OF AMERICAN RADIATOR & STANDARD SANITARY CORPORATION
40 West 40th Street, New York, N. Y.

Mail this coupon today for the Arco Cast Iron Pipe Manual.

Arco Pipe & Fittings Division
AMERICAN RADIATOR COMPANY
40 West 40th Street, New York, N. Y.

I am interested in Cast Iron Pipe. Send me your Arco Cast Iron Pipe Manual.

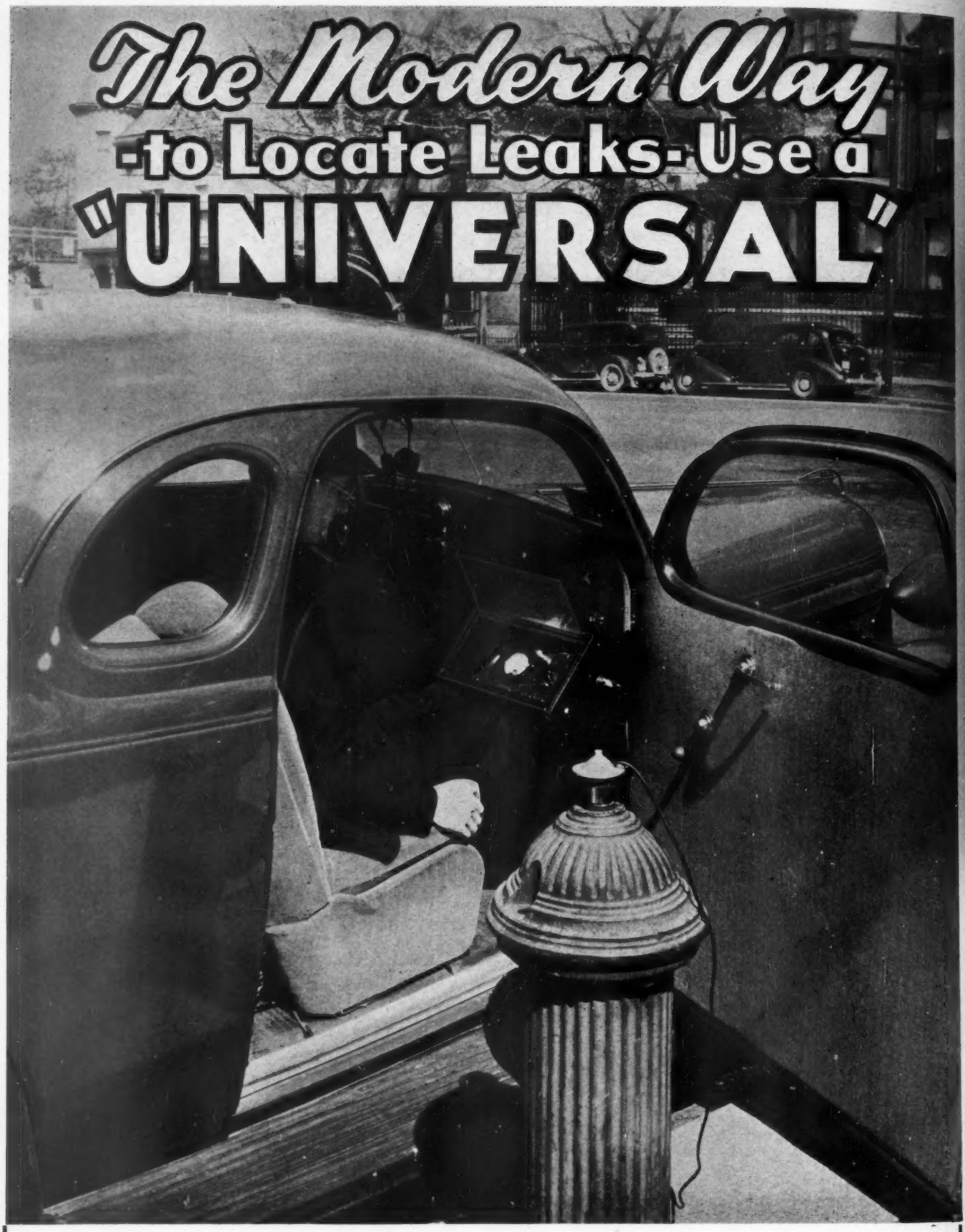
Name _____

Firm Name _____

Address _____

City _____ *State* _____

ARCO CAST IRON PIPE



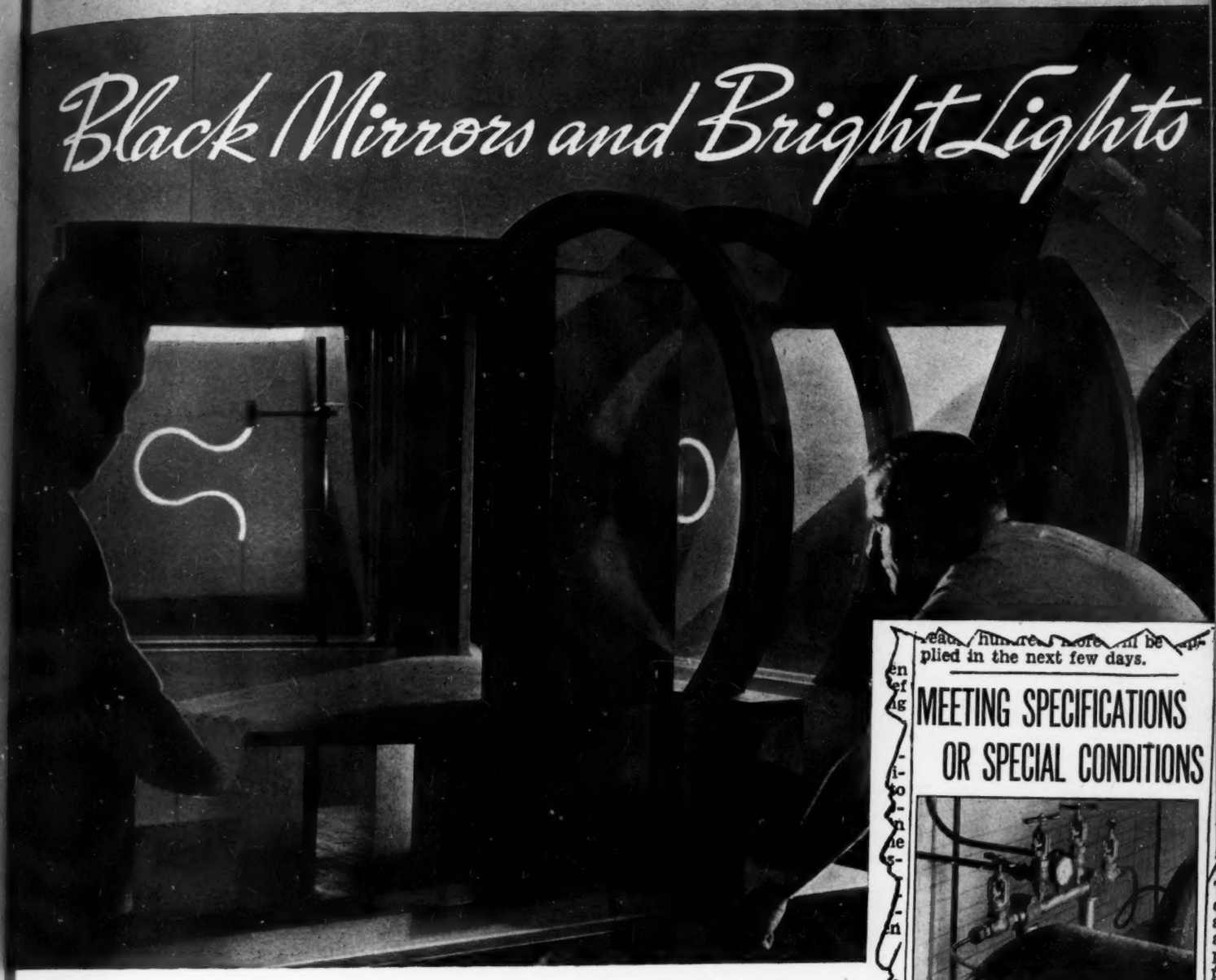
WRITE FOR OUR BOOKLET, "THE ANSWER TO YOUR WATER LEAK PROBLEMS."

VISIT OUR EXHIBIT AT BUFFALO CONVENTION, JUNE 7-11TH.

WATER LEAK DETECTOR CO. 155 N. THIRD ST. COLUMBUS, OHIO

THE MAGIC OF

Black Mirrors and Bright Lights



● No human eye has ever seen the stresses which pressure sets up in valves. No human eye has ever observed the action of such stresses—until their physical effects became visible.

But Crane—in its unending search for valve perfection—is not content to work out stresses by mathematical formulae. With the magic of black mirrors and polarized light, stress patterns reveal themselves as "shadows" in transparent model sections of valves. And so Crane "sees" the unseeable, that Crane valves may prove superior to every condition of service.

Since 1890, Crane has been continually making exhaustive tests on metals and alloys. Pioneering in metallurgical research has shown Crane what combinations of metal and design will do your job better. That is why standard Crane valves are so often the right answer to what seems to be "new" valve problems.

Look in your new Crane No. 52 Catalog for the details of 38,000 items and dimensions tested in the laboratory and proved on the job. Use it when you need valves, fittings, pipe or accessories. CranEquip for satisfaction.

SEE OUR EXHIBIT AT THE AMERICAN WATERWORKS ASSOCIATION CONVENTION, BUFFALO, NEW YORK, JUNE 7-12.

CRANE

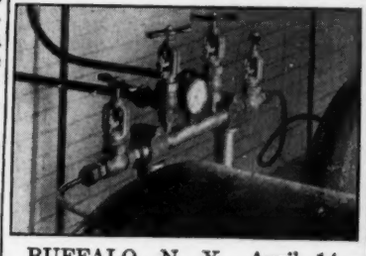
CRANE CO., GENERAL OFFICES: 836 SOUTH MICHIGAN AVENUE, CHICAGO, ILLINOIS

Branches and Sales Offices in One Hundred and Sixty Cities

VALVES, FITTINGS, FABRICATED PIPE, PUMPS, PLUMBING AND HEATING MATERIAL

plied in the next few days.

MEETING SPECIFICATIONS OR SPECIAL CONDITIONS



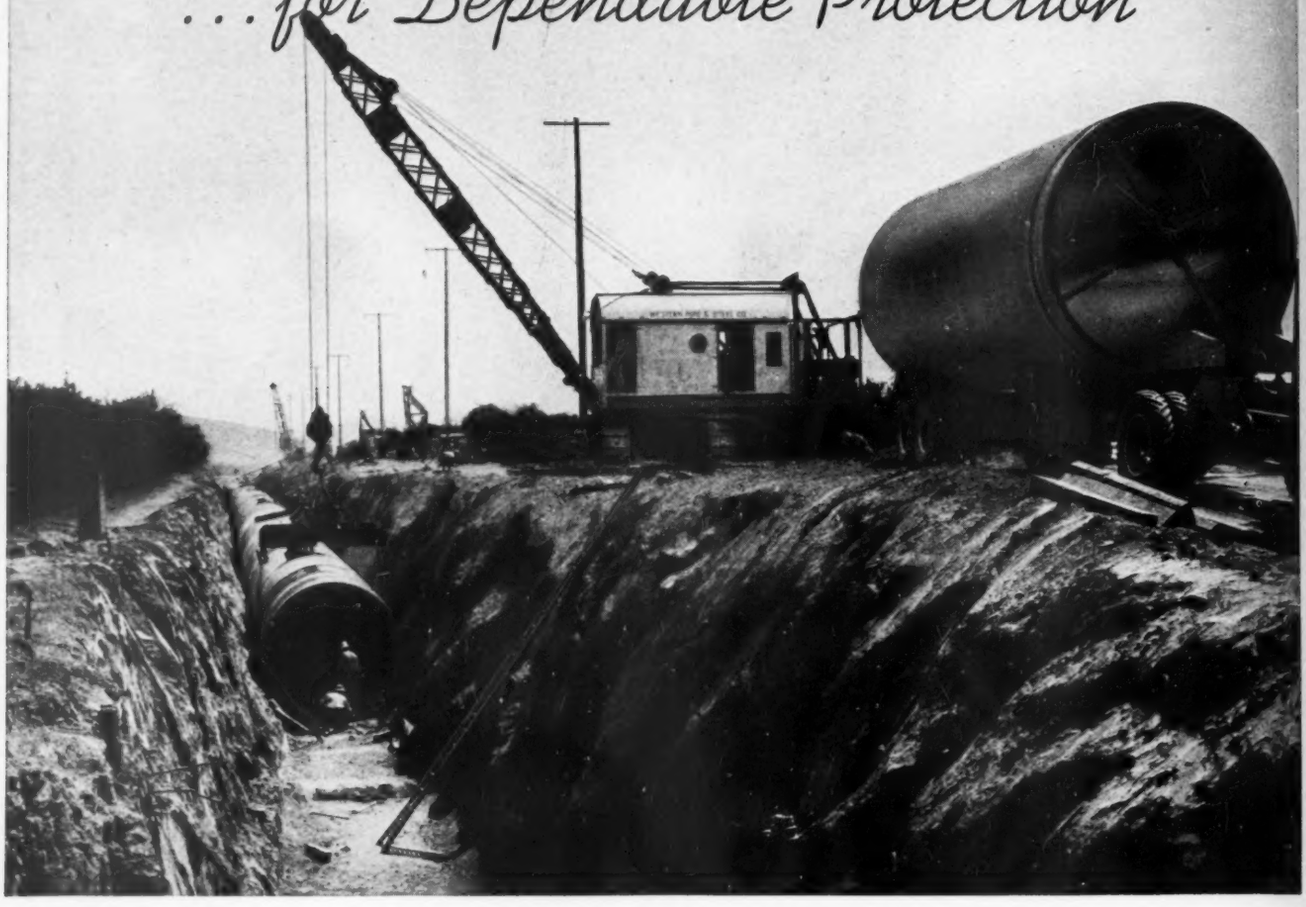
BUFFALO, N. Y., April 14—Whether you need valves that comply with A. W. W. A. specifications or valves that are designed to resist corrosive action, Crane can furnish them. Power operation using electric drive, hydraulic cylinders or air motors can be furnished where remote control is desirable.

There are approximately 38,000 items in the Crane line of piping equipment. Among that vast number, there are items that fit almost every requirement you have. Also important to water and sewer department officials is the fact that CranEquipment is served by a nationwide system of Crane branches and distributors that places commonly used Crane products practically on your doorstep.

On Pages 119-125, inclusive, of your Crane No. 52 Catalog you will find descriptions of Crane sluice gates and operating mechanisms. Also suggested typical installations. Use your No. 52 Catalog as an office aid on your piping problems as well as a source for high-quality piping equipment. You will find it valuable for both functions.

REILLY PIPE ENAMEL & PRIMER

...for Dependable Protection



WHETHER the job be protection of oil transportation lines, water storage tanks or water conduits—Reilly Coal Tar Enamel is inherently qualified to give permanent protection.

As an outside coating for steel pipe—it gives unequaled resistance against electrolysis and corrosion of soil acids and alkalis—and as an inside lining for water conduits—tanks—or service mains, prevents corrosion—tuberculation—and gives maximum flow at all times—eliminating expensive cleaning operations. Reilly Enamel is rigidly held to most exacting specifications and when properly applied cannot be stripped from steel and will not sag at temperatures approaching 200° F.—will not crack, peel or check when subjected to temperatures as low as minus 20° F. Consult Reilly for Pipe Line Protection—our service and facilities are yours to command.

Reilly
COAL TAR PRODUCTS

REILLY TAR & CHEMICAL CORPORATION

Executive Offices: Merchants Bank Building, Indianapolis, Indiana

2513 S. DAMEN AVENUE, CHICAGO, ILLINOIS 500 FIFTH AVENUE, NEW YORK, N. Y. ST. LOUIS PARK, MINNEAPOLIS, MINN.

FIFTEEN PLANTS TO SERVE YOU

LINK-BELT

STRAIGHTLINE EQUIPMENT

For Positive Results and High Efficiency

BAR SCREENS

GRIT CHAMBER EQUIPMENT

SLUDGE COLLECTORS
(For primary and final rectangular tanks)

CIRCULINE COLLECTORS
(For center-feed round tanks)

MIXING EQUIPMENT
(ROTARY AND AIR)

FINE SCREENS

VOLUMETRIC CONTROL
FOR SEWAGE *and* SLUDGE PUMPS

Send for Catalogs *Address Nearest Office*

LINK-BELT COMPANY

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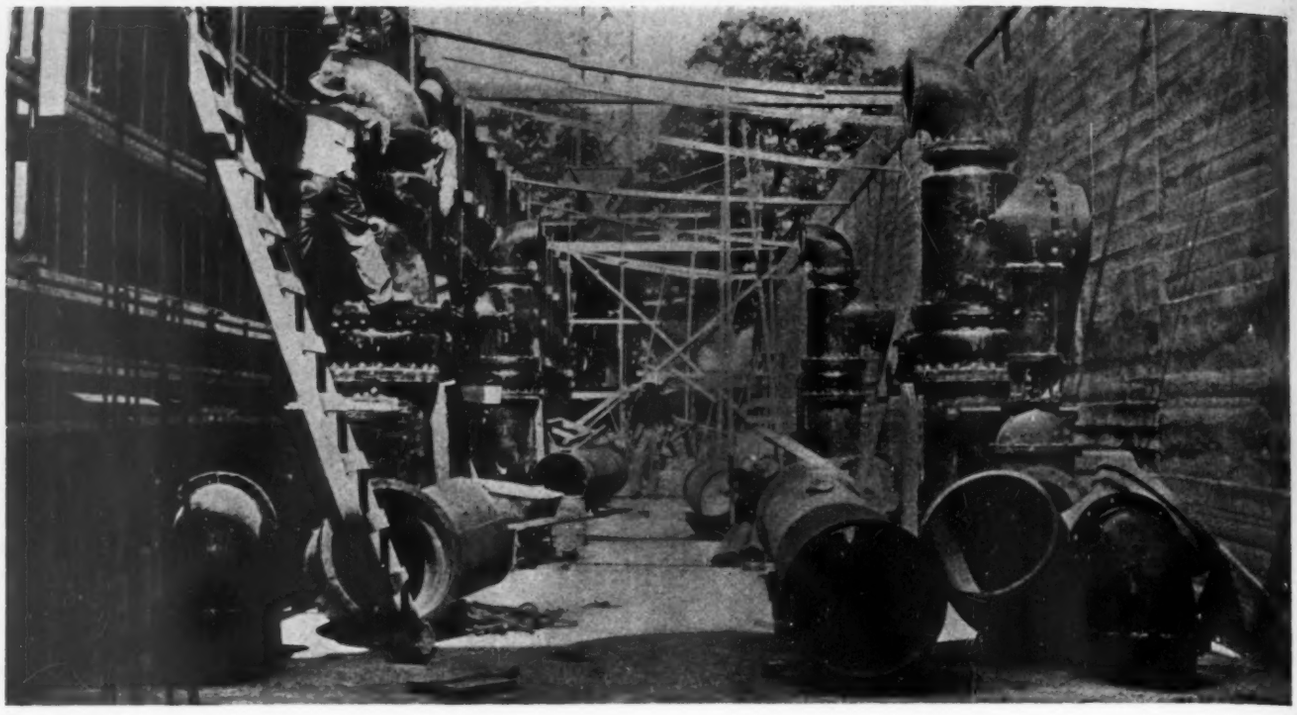
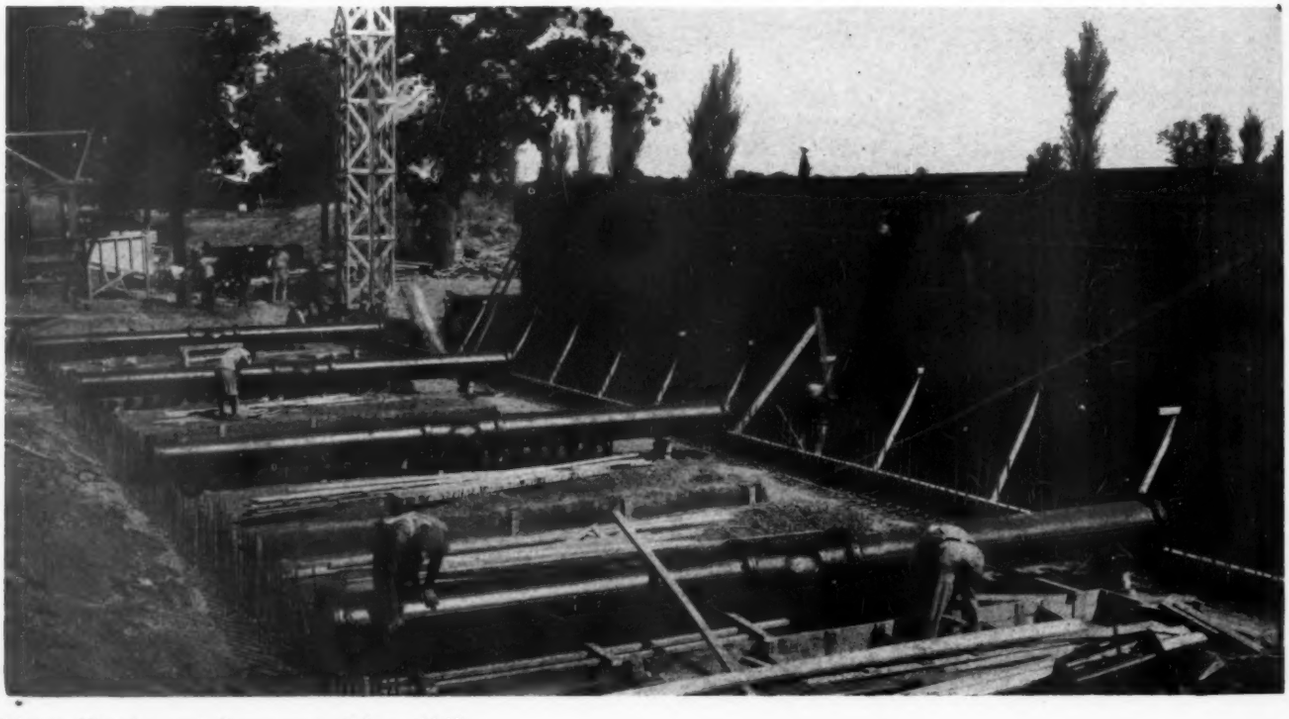


These photographs, showing Acipco cast iron pipe and fittings being installed in the recently completed addition to the great Bachman Filter Plant, Dallas, Tex., illustrate Acipco's complete manufacturing facilities and experienced service—both of which have proven themselves extremely helpful in countless water works and sewerage projects throughout the United States and in foreign countries. For detailed literature address Acipco office nearest you.

AMERICAN CAST IRON PIPE CO., BIRMINGHAM, ALA.

New York City Chicago Kansas City Minneapolis
Cleveland Pittsburgh Dallas Los Angeles San Francisco



RATE CONTROLLERS
FILTER GAUGES
VENTURI TYPE METERS

SIMPLEX LEADS AGAIN!

In 1910 SIMPLEX offered the first direct acting balanced valve rate controller—for years accepted by discerning water works men as a standard.

Now—SIMPLEX again offers the

FIRST—Rate Controller for installation in a vertical line.

FIRST—Sand Expansion Indicator and Recorder.

FIRST—Air Operated Filter Gauges.

FIRST—Meter actuated by pump casing taps.

FIRST—Summation Recorder showing total flow thru entire battery of filters.

See our exhibit
Buffalo Convention
A.W.W.A.

SIMPLEX VALVE & METER CO.
6743 UPLAND STREET • PHILADELPHIA, PA.

Sewage Treatment Equipment Exclusively since 1893

P.F.T.

WASTE GAS BURNERS

FLOATING COVER DIGESTERS

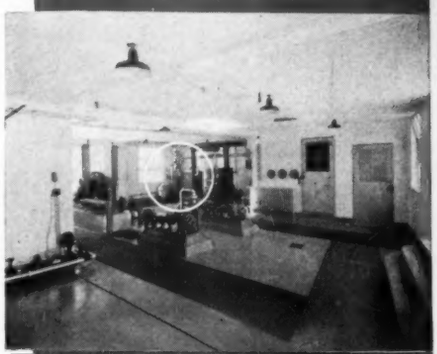
OVER forty years of specialized effort in serving the consulting engineer and municipality with sewage treatment equipment—forty years of doing one thing well—is represented in each item of equipment of the P. F. T. Line of today.

That we have done our work well and reaped the reward of merit and confidence is witnessed by the thousands of P. F. T. installations in the field—Floating Cover Digesters—Rotary Distributors—Sprinkling Filter Plants—Flame Traps—Twin Tank Controls—Alternating Siphons—Waste Gas Burners—and many other accessory equipments.

Consider the value to you of using time tested, universally approved P. F. T. Sewage Treatment Equipment in your plant.

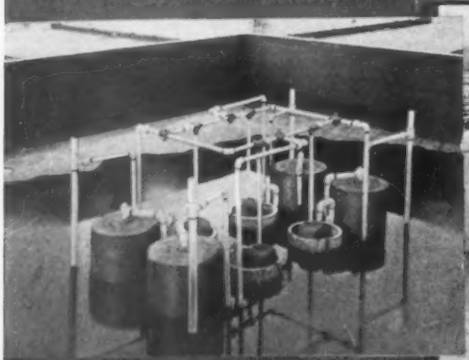
May we furnish you with bulletins on any or all of the P. F. T. Line of specialized Sewage Treatment Equipment?

ROTARY DISTRIBUTORS

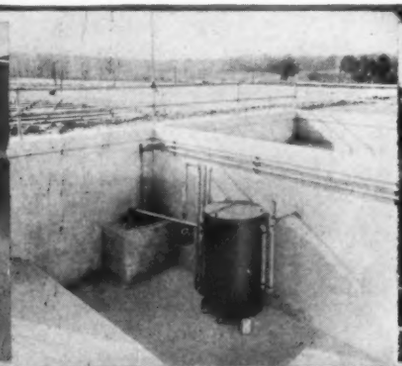


FLAME TRAPS

PACIFIC FLUSH-TANK CO.
4241 Ravenswood Ave., Chicago, Ill.
NEW YORK LOS ANGELES CHARLOTTE, N. C.

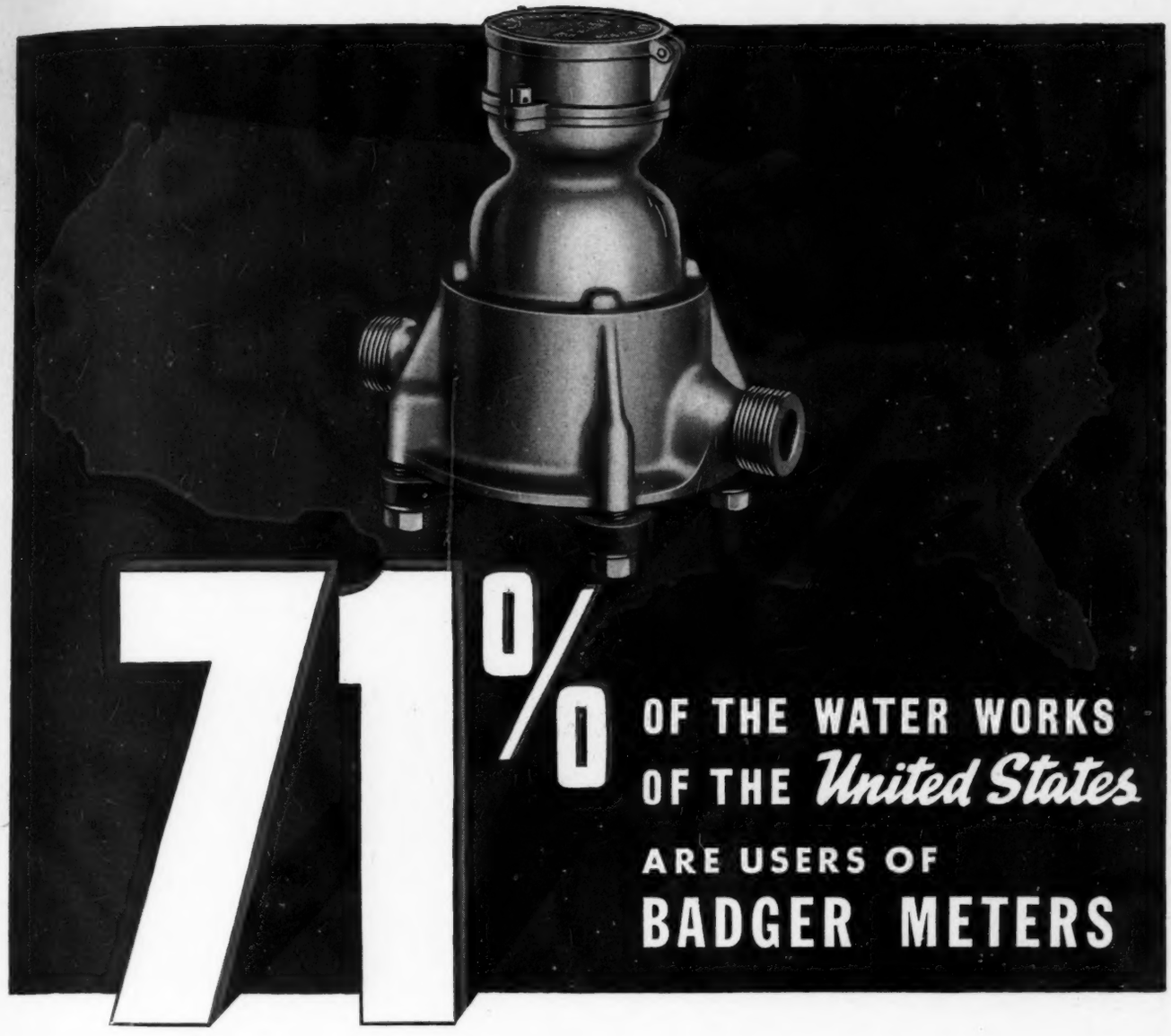


ALTERNATING SIPHONS



TWIN TANK CONTROLS

SPRINKLING FILTER PLANTS



More than five billions of dollars are invested in the nation's water works facilities . . . to provide for an average daily per capita consumption of water in the United States of 100 gallons.

And 71% of the most important systems have purchased Badger Meters for their known dependability and economy of performance. Such amazing majority of acceptance of Badger Meters has been won because Badger Meters deliver service. They take little "time out" for inspection and repairs . . . they emphasize economy of operation . . . they produce maximum revenue by accurate operation. The smallest trickle or maximum capacity flow is faithfully recorded by Badger Disc Meters . . . which have the largest capacities, size for size, with the least absorption of pressure.

• • •

Badger Meters on your lines assure Durability . . . Large Capacity . . . Extreme Accuracy . . . Minimum Maintenance . . . Low Pressure Absorption.

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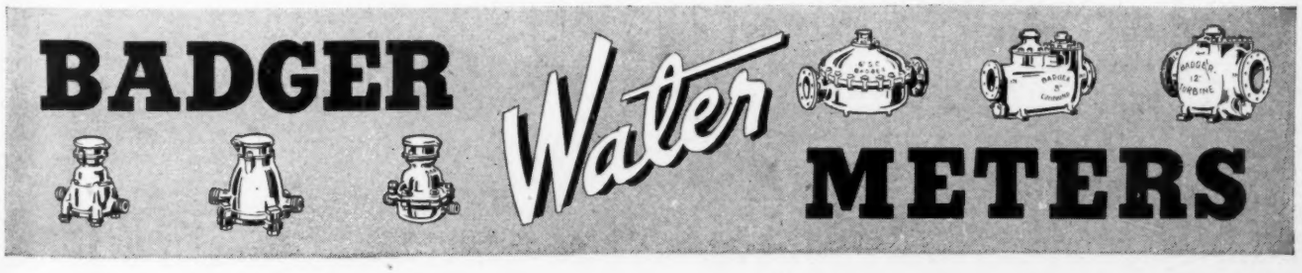

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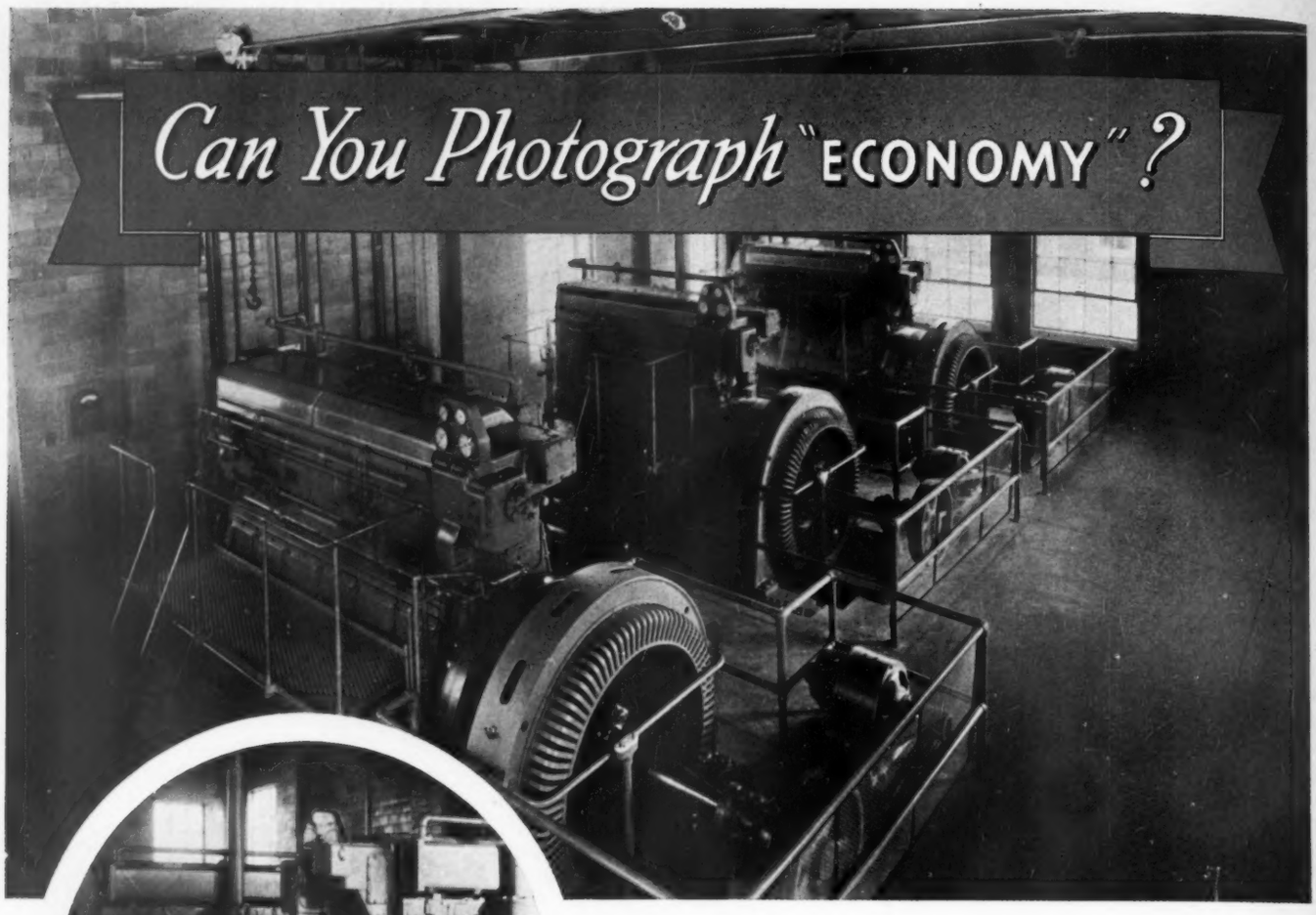

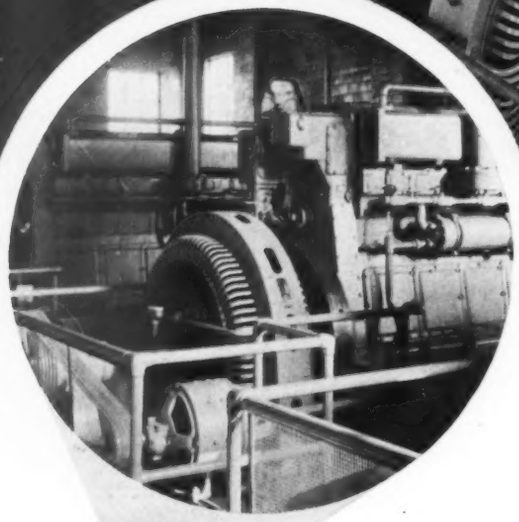

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WATER WORKS & SEWERAGE

E. S. GILLETTE, Publisher

L. H. ENSLOW, Editor

ARTICLES AND AUTHORS Scheduled for Future Issues

"The Filtration Plant of Hammond, Indiana" will be described in our June issue, in a long delayed article from Leo Besozzi, Supervising Engineer, of Hammond's Water Department. The novel and unique features incorporated in the design of Hammond's new plant are set forth and commented upon, based upon operating experiences and plant performances. (This article which has been scheduled for sometime has been unavoidably held out of this issue at the last minute, for which our apologies to the author and our readers.—Ed.)

"The Combination Sewage Works of Cedar Rapids, Iowa."—Represents the first development of consequence, involving a cooperative effort, wherein the taxing municipality provides industrial waste treatment in a separate chemical pre-treatment plant along side of, and delivering effluent to be "finished off" in, its domestic biological treatment works. In his article, briefly describing the pioneering combination works, which serve jointly the industrial and private taxpayer, Howard R. Green, Cedar Rapids' consulting engineer, discusses the good and bad features of the project. His analysis is amplified with operating experiences, experimental findings, and plant performance during the first year of operation. This is to be the initial article on an important project, justifying "follower" articles dealing with integral considerations of this new venture in municipal service to industry, on an equitable cost basis.

"The Magnetite Filter in Sewage and Water Treatment"—is a contribution from Samuel I. Zack, Sanitary Engineer, Filtration Equipment Corporation. It describes the interesting features of those novel self-cleansing magnetite filters, their performance records, utility and economy features in plants equipped; recent developments, involving introduction of the down-flow type with finer grained crushed magnetite as the filtering medium. Specifications on the newest units going into the sizeable Atlanta and Denver works, and the Minneapolis-St. Paul plant, are set forth. Preliminary results from a water works experimental installation, (described in our last issue by Harry U. Fuller as "The Algae Strainer"), are also briefly presented.

Those who read the articles in the Reference and Data Section of this issue, dealing with "Meter Testing, Repair and Maintenance" will need no urge to watch for the forthcoming contribution by **Clem A. Gallagher,** Louisville's Superintendent of Services and Meters, on the **"Maintenance of Water Meters."** It constitutes a sequel to his earlier contribution found in the Reference and Data Section of this issue.

"Water Loss and Leakage Control" is a contribution from Johannesburg, South Africa. Mr. M. Udwin, Rand Water Board's Chief Engineer, relates their experiences with leakage control and tells how it has been possible to reduce unaccounted for water (water loss) to the extraordinary low figure of 1.34 per cent. More remarkable, is the fact, that this becomes a sustained efficiency in the operation of Mr. Udwin's distribution system. It would appear that America has something to learn from the Transvaal.

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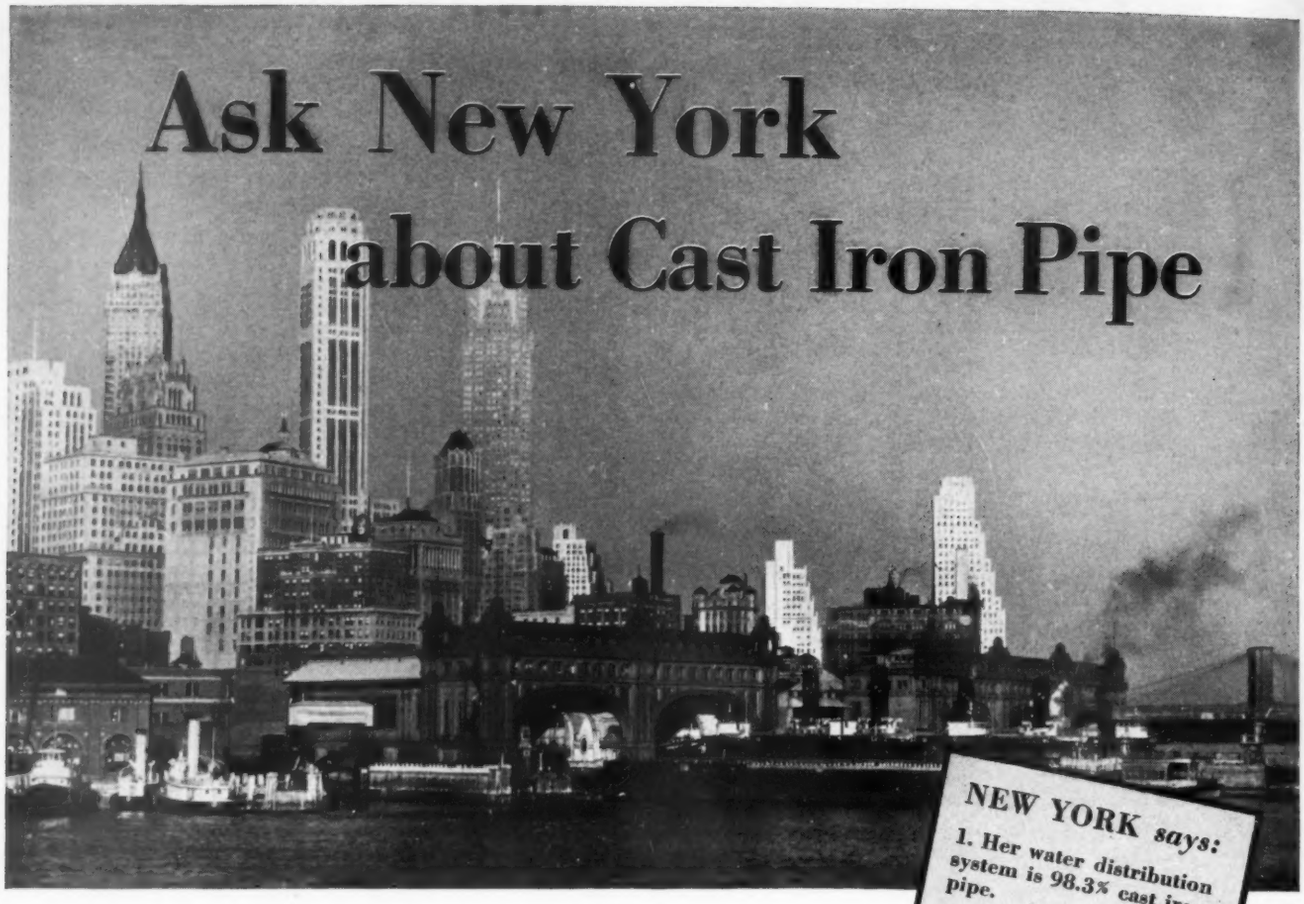
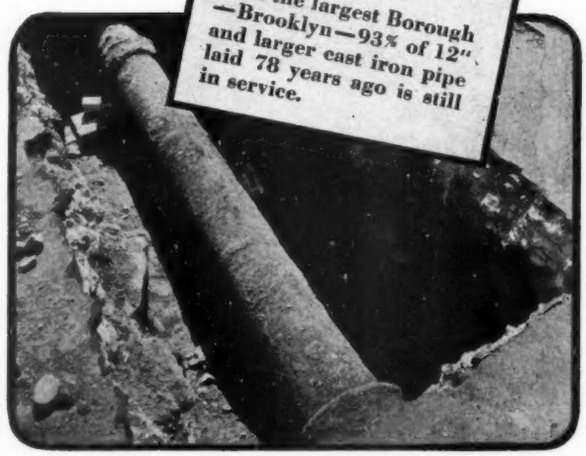


NEW YORK *says:*

1. Her water distribution system is 98.3% cast iron pipe.
2. The oldest cast iron pipe in service was laid 106 years ago.
3. The distribution system contains 4610 miles of cast iron pipe.
4. In the largest Borough —Brooklyn—93% of 12" and larger cast iron pipe laid 78 years ago is still in service.

GRIDIRONED by subways that thread their way through a crowded maze of conduits, the City of New York is a tough testing ground for pipe. With 4610 miles of cast iron pipe in the water distribution system, some of it in continuous service for more than a century, New York has had long and large experience with cast iron pipe. Much of this pipe is meeting conditions of traffic, above and underground, and population congestion, undreamed-of when it was laid generations ago. New York's verdict is this: her water distribution system is 98.3% cast iron pipe. More than 95% of the water distribution systems of our 15 largest cities consists of cast iron pipe. Cast iron is the standard material for water mains. Its useful life is *more than a century* because of its effective resistance to rust. It is the one ferrous metal pipe for water and gas mains, and for sewer construction, that will not disintegrate from rust. Available in diameters from 1¼ to 84 inches. For further information, address The Cast Iron Pipe Research Association, Thos. F. Wolfe, Research Engineer, 1013 Peoples Gas Building, Chicago, Illinois.



Section of old cast iron water main laid in New York 106 years ago, and still serving.

CAST IRON PIPE

The Standard Material for Underground Mains

Water Works and Sewerage—May, 1937

WATER WORKS AND SEWERAGE
A GILLETTE PUBLICATION
VOL. 84 MAY, 1937 No. 5

RECENT BETTERMENTS TO BUFFALO'S DISTRIBUTION SYSTEM

By ALAN D. DRAKE and WILLIAM J. KELLY
Director of Water *Gen'l Supt. Distribution*
Buffalo, New York

THE recent changes in Buffalo's method of distributing water and the trends that made these changes desirable, if not mandatory, may be better understood if a cursory look at the historical background of the system is taken.

Buffalo obtained its water system, on which there was an 11,000,000 gal. reservoir, by purchase from private interests in 1868. As early as 1874 the need of a larger distributing reservoir was felt and in that year a site at a much higher elevation was purchased on which to build it. However, subsequently, some doubt as to its necessity must have arisen for the 1881 Annual Report of the Department states, "The Water Works have reached a point where consideration of the two systems of service by which the city is supplied ought not to be further postponed. Whether economy would be promoted by continuing or uniting these two systems of service is a matter which experts ought to be invited to determine."

If these experts rendered an opinion it must have been favorable to the continuance of the dual high and low service system that had been in vogue in the Buffalo Water Works ever since its inception. In any event, the construction of a new reservoir for the purpose of reinforcing the low pressure service was begun in 1880 and completed in 1894. This reservoir had a capacity of 116,000,000 gallons, representing a two days' supply to the low pressure service which covered three-fourths of the city's area. It provided a pressure range, with full reservoir, of only 15 lbs to 35 lbs.

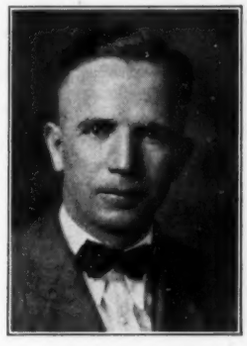
In conjunction to this reservoir distributing system was a limited high pressure zone. It received its pressure by direct pumpage and existed solely because it was at an elevation too high to be included in the reservoir system.

As the city grew, Buffalo in common with many other cities discovered that, on account of the erection of larger and higher buildings, industrial water requirements, and the desire for more efficient fire protection, there was a real need for higher pressures in the low pressure reservoir system. From time to time the boundaries of the low pressure zone had been constricted to meet these conditions and, on account of the rapid growth of the high pressure area, instead of a system as visualized at the time of the construction of the reservoir, it was found in 1934 that a decided change had taken place in the manner in which water was being distributed. The low pressure system had now become the subordinate system and was consuming only one-fifth of the total water pumped.

Shortly after the senior author became Director of Water on January 1, 1934, he was confronted with the necessity of meeting the growing demands for higher pressure by the residents and industries of South Buffalo, which was the only remaining section of the city being served from the low pressure reservoir system.

The Authors

Alan D. Drake



Wm. J. Kelly

After careful consideration of the benefits to be derived from the change, and after consultation with engineers of the Fire Underwriters Association, it was decided that the overall efficiency of the system would be materially increased by placing it on a single pressure system. Because of the elevation of the existing reservoir, this involved its abandonment.

The plan to eliminate the reservoir met with considerable opposition from persons not familiar with conditions then prevailing in the water works system. The fears were those of discarding the large storage capacity available should there be a possibility of a complete shutdown of the pumps at a future time. But, it must be remembered had this happened the advantage would have been confined entirely to the low pressure zone and four-fifths of the city would have been deprived of water in any event. Consumers fearful of consequences were in the area including many of the principal industries, the best commercial districts and the highest class residential section. Such a calamity, in spite of the presence of the reservoir, would have saved nobody's face.

The Betterment Plan

Plans and specifications providing for the erection of three strategically located elevated tanks of 2,000,000 gallons capacity, each, were drawn under the supervision of William H. Grotz, Assistant Engineer of the Division of Water and were presented to the Commissioner of

Eastside
2,000,000
Gallons

Northside
2,000,000
Gallons

Southside
2,000,000
Gallons

Public Works and the Common Council for their approval early in 1935.

Mains Found in Excellent Condition—

To predetermine an elevation of the tanks that would permit them to most effectively serve the present system, and likewise be in accord with any expected or probable changes in the future, a Pitometer distribution survey was made. In addition to determining the height of the tanks, the survey proved that the system was well fortified with feeders, that there would be no necessity for laying larger mains for some years to come and that the feeders were free from closed valves and other obstructions. The Hazen and Williams coefficient was computed for practically all the large cast iron mains and was found to be higher than anticipated values, based on age of the mains. In some cases mains in service for 28 years had a carrying capacity comparable to that of new pipe.

The Tanks

The tanks, which are of similar design, are of the radial-cone type (see pictures), 122 feet inside diameter and 25 feet in depth. Each tank is capable of supplying the system with 2,000,000 gals. with a pressure drop of only 10.9 lbs. per sq. in. They were erected on three widely separated high points of the city and are so placed that they are inter-connected and balanced by 36-inch feeder mains (see map). The foundations for the tanks, and the piping necessary to connect them to the system, were installed by the local Works Progress Administration. Each tank is equipped with a cone-valve, which prevents overflow by automatically closing when the tanks are filled to capacity. Telemeters have been installed on all tanks through which the elevation of the water in the tanks will be recorded on pressure gauges in the pump-room and a twin set of recording gauges in the office of the Chief Engineer.

The Effects

Much apprehension was felt when the idea of increasing the pressure in the old low pressure district was being formulated and, as there is pipe in this section that has been in the ground for 84 years, there was some reason for such alarm. This was fully borne out during the first week of higher pressures when leaks caused by weak joints and broken pipes kept the entire Maintenance Department on the alert. After these first breaks were repaired the system once more functioned normally and since that time no serious difficulties have been encountered.

The increased pressure in the old low pressure zone, also made necessary the immediate repair of a great many fixture and service leaks that may have been leaking unnoticed. At least many had gone unrepaired for years.

It was estimated that on account of increased pressure there would be an 8,000,000 gal. increase in the daily consumption. However, in the first year of its existence the single pressure system actually increased the pumpage less than 6,000,000 gals. per day. This in the face of considerable improvement in industrial conditions which in Buffalo has always had a marked influence on water consumption.

It must be admitted that a mild winter had something to do with reducing the expected increase in pumpage but the principal factor in accomplishing this was the relaying of 4.2 miles of pipe in one of the oldest sections of the city. It had been long realized that, due to the nature of the ground in which these pipes were laid, their replacement in the near future would become imperative. The Division of Water took advantage of a pre-offered W. P. A. project and renewed these pipes and with much economy to itself.

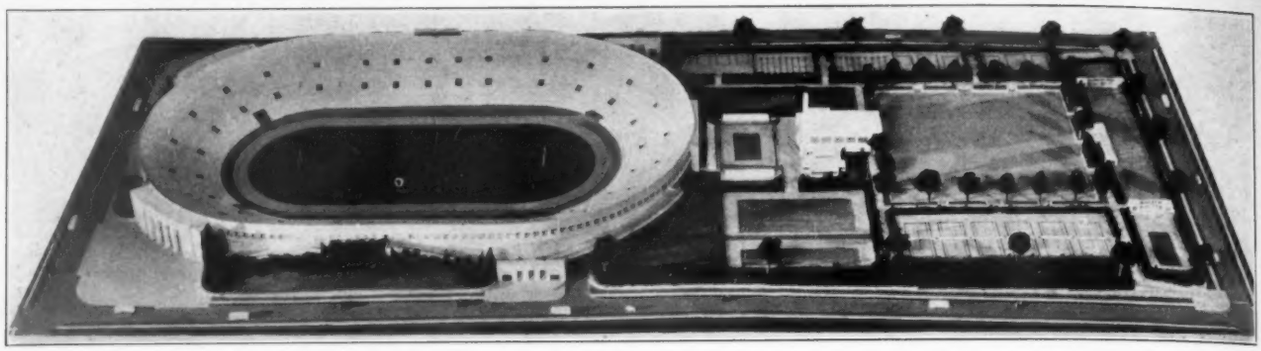
Closed Valves Eliminated

The single pressure system offered one objective that has been the aim of the present Division of Water, and probably all previous administrations, in that, with the exception of a small booster section, all the valves of the system would be open. In general the division valves between the two pressure systems were contiguous to large feeders and, in addition to being closed and creating almost one hundred unnecessary dead ends, were a distinct handicap to good distribution. These valves had been closed for as long as 42 years and, to prevent the entrance into the system of sand and other deposits that had clogged these dead ends long before the filtration plant was contemplated, the valves had to be opened with much care.

Benefits Noted

The immediate benefits noted by the change-over were, first of all an increase of pressure in the sections of the city where the pressure was too low. The average pressure throughout the city became more nearly uniform. While the average and minimum pressures of the old low pressure area were raised 30 lbs. the maximum pressure

Buffalo's Long Inadequate Service Reservoir on Valuable Land in a Central Location. With the Completion of the Elevated Storage Program Is Being Converted Into a Worthwhile Municipal Asset Pictured Elsewhere with This Article.



Architect's Model of Buffalo's Municipal Stadium and Recreation Center. Accessibly Located in the Obsolete Reservoir, Superceded by Only 6,000,000 Gal. Elevated Storage, Upon Completion in 1937 Becomes a Real Asset to the City and Meets a Long Felt Need.

has been increased only 15 lbs. A great improvement in the regulation of the pressure in the outlying sections of the city has been noted. The extreme daily variations being reduced from 30 lbs. to 10 lbs. in differential. The pressure at the pumps has been reduced, the pumping rate is more uniform and there has been a small decrease in the pressure in the old high pressure area.

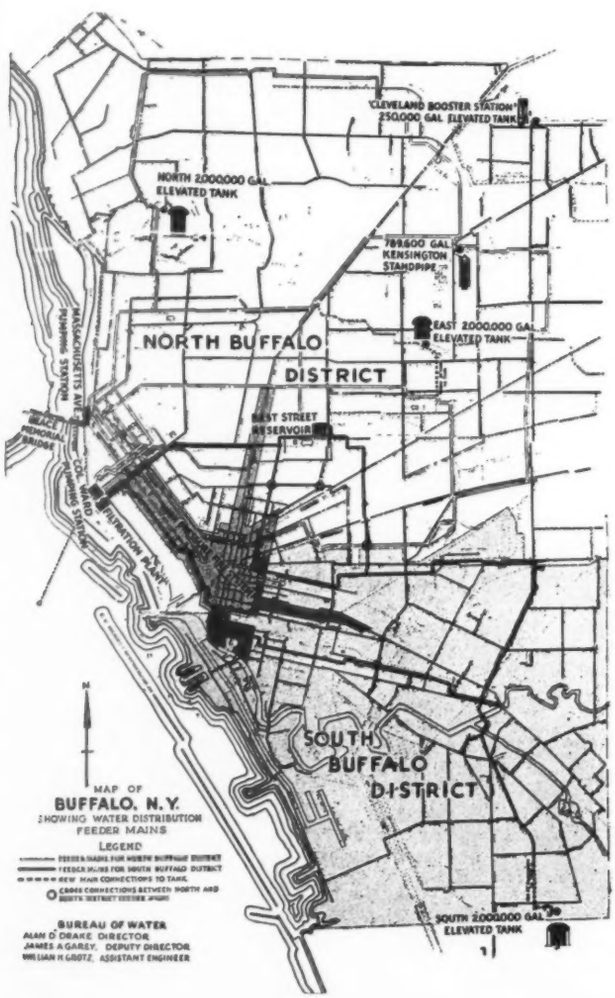
Some of the mains in the old high pressure district were carrying velocities that were too high. These have been reduced by uniting the two systems. In others, where the velocities were extravagantly low, they have been increased; thereby, creating a better balance and postponing the time when additional feeder capacity will be necessary.

The new arrangement is a decided improvement over the old in that storage capacity, although decreased, has been effectually distributed throughout the system and for the first time has been made available to the entire city. The elevation of the full water line of the stored water has been raised from 685 to 752 feet above sea level. It is expected that the economic value of an improved fire protection system will be directly shown in reduced rates of insurance.

To those persons who take an interest in the beauty of Buffalo's sky line, it must have been very gratifying to note the disappearance of many unsightly water tanks, whose presence on sprinkler systems have been made unnecessary by increased pressures available.

The single pressure system presents one hazard in the possibility of ice jams at the intake. The present administration made a thorough study of such a contingency and, by improvements and precautions that have been taken at the intake, feels that this source of danger has been reduced to an absolute minimum.

The clear water reservoir at the Filtration Plant has a capacity of 30,000,000 gallons, a normal six hour demand. The principal 60 inch main leading from the Ward Pumping Station had been previously duplicated and, with the reliability of modern pumps in mind, it is felt that every reasonable precaution has been taken to insure uninterrupted water service for Buffalo.



Map of Buffalo, Showing Feeder Main System, Cross-Over Connections Between Direct Feeders, Old Reservoir Location and Location of the Three New 2,000,000 Gal. Tanks.

Disposition of Old Reservoir

The abandonment of the reservoir released to the proponents of a municipal recreational center and stadium, a publicly owned, centrally located site with a contour so easily adapted to that of a stadium that it would reduce construction costs and make a much desired project possible.

In addition to the regular distribution system there are two other water systems in Buffalo. One has boosted pressure and serves a small district on high terrain at the north-eastern extremity of the city. The other is an independent high pressure fire system, operated by the Fire Department, with separate mains and pumps. It provides fire protection for the congested value district and operates at a maximum of 300 lbs. pressure.

The Division of Water is a branch of Buffalo's Department of Public Works, of which George J. Summers is Commissioner. Alan D. Drake is Director of Water and James A. Garey is Deputy Director.

In closing, the authors wish to acknowledge the cooperation of Mr. Frank O. Nehin, Pitometer Engineer, for his valuable assistance in the preparation of this paper.

ANNOUNCING— A. M. RAWN AS ASSOCIATE EDITOR WATER WORKS & SEWERAGE

A. M. Rawn

WE take pleasure in announcing that with this issue, A. M. Rawn of Los Angeles, becomes Associate Editor of WATER WORKS AND SEWERAGE.

To the older readers of this magazine Mr. Rawn needs no introduction. To its pages, he has been a frequent contributor of helpful operating and maintenance articles pertaining to sewers and sewage treatment.

On the Pacific Coast, as Assistant Chief of the Los Angeles County Sanitation Districts, he has long been a leader in the sewerage field and is well known for the original and fruitful research and development work in sewage treatment, carried forward under his direction. In recognition of such work, Mr. Rawn has served, and still is serving, on important committees in the American Society of Civil Engineers and the California Sewage Works Association.

Rawn, a native of Dayton, Ohio, "took root" in California soil as if he sprouted there originally rather than having been transplanted to become an asset in the way of an adopted son. He started his engineering career railroading and later went into irrigation and reclamation work, serving on some of the most important irrigation projects in the West and working his way up to Project Manager. This position he left to join-up with the 605th Engineers A.E.F. for over-seas service as 1st Lieutenant of Engineers during the World War. After his discharge he completed an assignment on the Columbia Basin Project in Washington, and then went to the new Los Angeles County Sanitation District in 1924.

During his connection with the Sanitation District much that was new, generally helpful and of practical value, has come out of its laboratories, and as the result of studies and field tests on sewer design, operation and maintenance, and large scale experimentation and demonstration at the District's treatment works. As a result, the literature on sewerage and sewage treatment has been repeatedly enriched by articles and reports developed by Mr. Rawn, or produced by members of his staff under his encouragement, guidance and stimulation.

Characteristic of the man, is his reply to our invitation. He stated he did not believe that he was equipped to serve as Associate Editor, because of the fact that he had been deprived of the opportunity to carry through his college work to the point of gaining a diploma—*his* "degrees" being those from the University of hard-knocks. To him we replied that little did we care and, what's more, we were after the *man*, and not the name or the "handle" which might go with it.

Aside from being a leader in his chosen field, "A. M.," as he is familiarly known, has that personality which makes him a part of the West—and, so well liked by all who know him. His standing and leadership have taken him to the Vice-President's Chair of the California Section of A.S.C.E., and the Presidency of the California Sewage Works Association. On the Board of Direction of the last he now serves.

With this sparse introduction; We take pride in presenting to our readers "A. M." Rawn, Associate Editor of WATER WORKS AND SEWERAGE.

▼

Telling the Other Fellow

In his recent taking over of the chairmanship of the muchly alive and productive Canadian Section of A.W.W.A., Mr. A. V. Buchanan, Manager of Utilities, London, Ont., contributed bits of sound philosophy and good advice in his remarks made on the occasion of acceptance at the recent Montreal Convention. Here follow a few high-lights taken from Mr. Buchanan's thought impelling remarks.

"We have one of the best technical organizations in Canada and our Section is recognized by the parent body as having a very high standing. But, do not let us take ourselves *too* seriously. . . .

"Of course, our technical papers and discussions are important, but our *most* important consideration is our relationship to, and our faith in, our fellow man."

(Speaking of Conventions) "If there is not too much "Whoopee" the parties may be worth as much to us as our technical sessions . . . . and, just a word of caution, don't let us come with the idea that our only purpose is to tell the other fellow. The representative of the largest city can learn something from the superintendent of the smallest village.

"As engineers of water supply, we should not forget our true function. We are not merely scientists and mechanics, but are definitely interested in practical application of science and mechanics in terms of money economy". . . . "The saving of money, however, means little in itself, our job is not just engineering and accounting; the economic factor is only a means to an end. The real end, itself, is public service."—*Buchanan.*

THE SEWAGE DISPOSAL PROJECT OF BUFFALO

Holds Interest to Water Works Men—

By PAUL HANSEN

Greeley and Hansen, Engineers, Chicago

Water works men gathered in Buffalo for the annual convention of the American water works fraternity—A. W. W. A.—will find the Buffalo sewage disposal project of particular interest. This is so, because one of the important functions of sewage treatment by Buffalo is to protect several public water supplies. Also, because sewage disposal involves a number of pumping, metering, hydraulic and construction problems similar to those encountered in water supply practice. Then it must be remembered, too, that sewerage and sewage disposal is pertinently related to water supply. Water-works "deliver" new water; sewerage-works take it away after it has been used—frequently to send it downstream to be "delivered" anew by another water works, and another.

THE sewage disposal project of Buffalo has the following major objectives:

(1) The removal of much pollution from the Buffalo River and its immediate tributaries.

(2) The relief of Buffalo's harbors of undue pollution.

(3) The removal of pollution from Niagara River and reduction of the bacterial content of its waters to correct the pollutional load on the water purification works of communities from Buffalo to Lake Ontario.

(4) Diversion of sewage from Delaware Pake Lake.

(5) The provision of storm water relief in two inadequately sewered drainage areas.

The Author

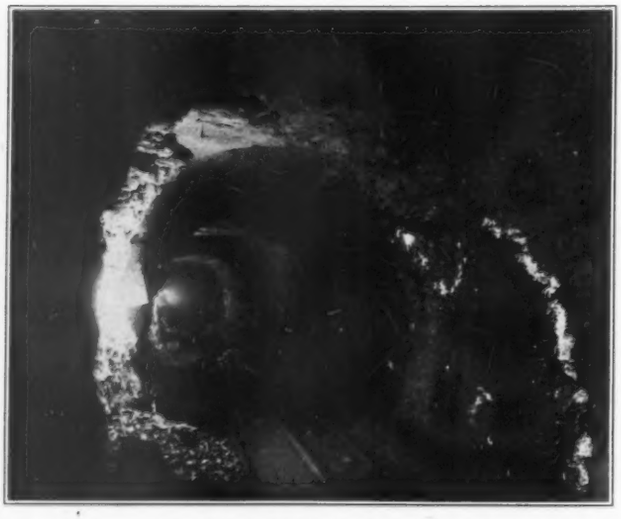
To accomplish these objectives requires intercepting sewers, pumping stations, treatment works and storm relief sewers. The general location of these elements are shown on the accompanying general plan.

The intercepting sewers will collect the sewage from sixty existing sewer outlets, now discharging untreated sewage, and convey it to the main pumping station and treatment works on Bird Island. The design of the intercepting sewer is predicated on the requirements of a population of 1,100,000. These sewers have a total length of about thirteen miles and vary in diameter from two feet to eleven and one-half feet. They will intercept from two and one-half to three times the dry weather flow of sewage. About four miles of intercepting sewer is being constructed in rock tunnel, something under a mile in earth tunnel and the remainder in open cut.

The main pumping station is located on Bird Island and has a nominal capacity of 600,000,000 gallons per day and comprises six 100,000,000 gallon pumping units, each driven by a 600 horsepower synchronous motor. The pumps will deliver directly to the new sewage treatment works, like wise on Bird Island.

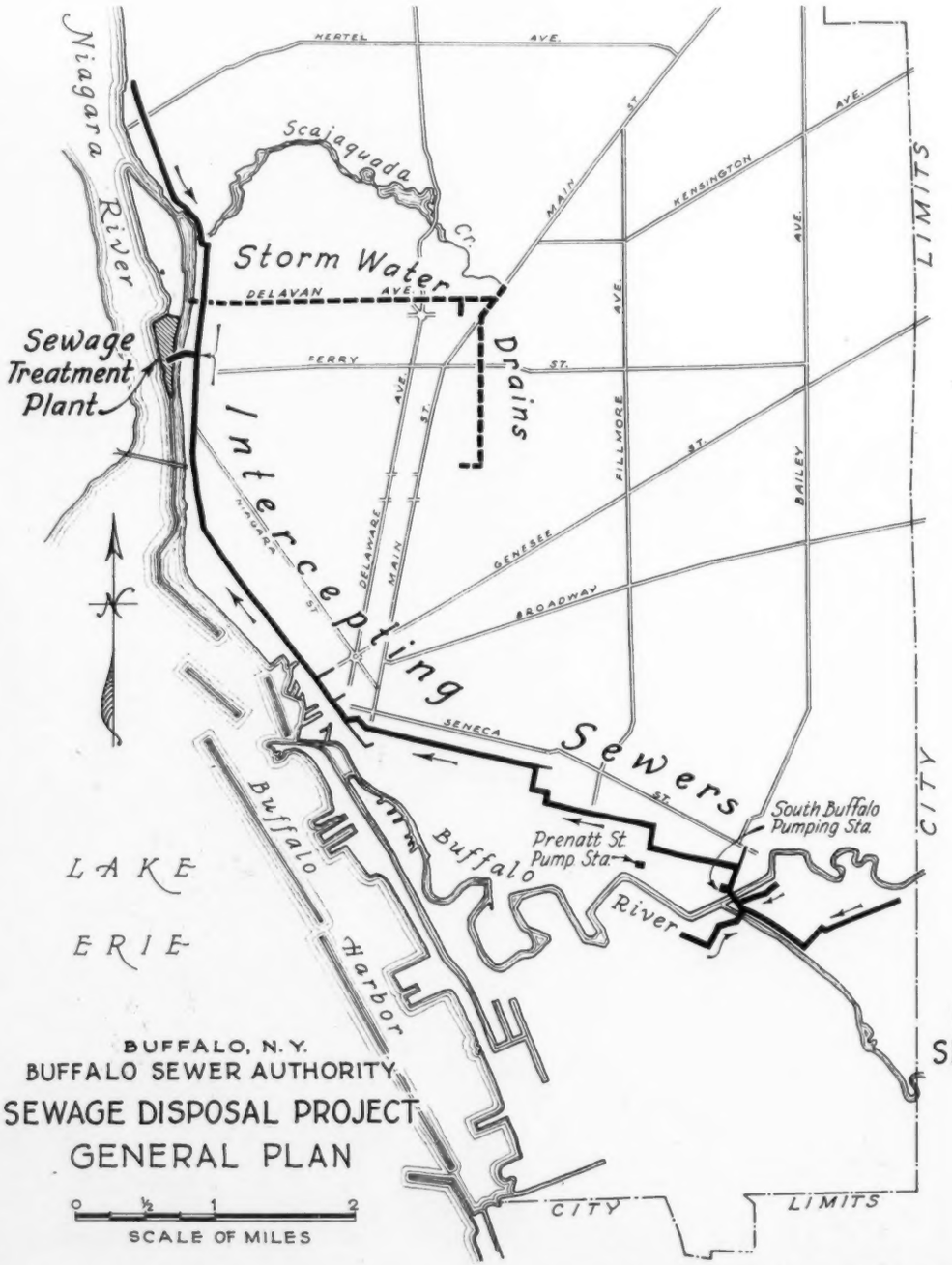
$3,000,000 Treatment Works

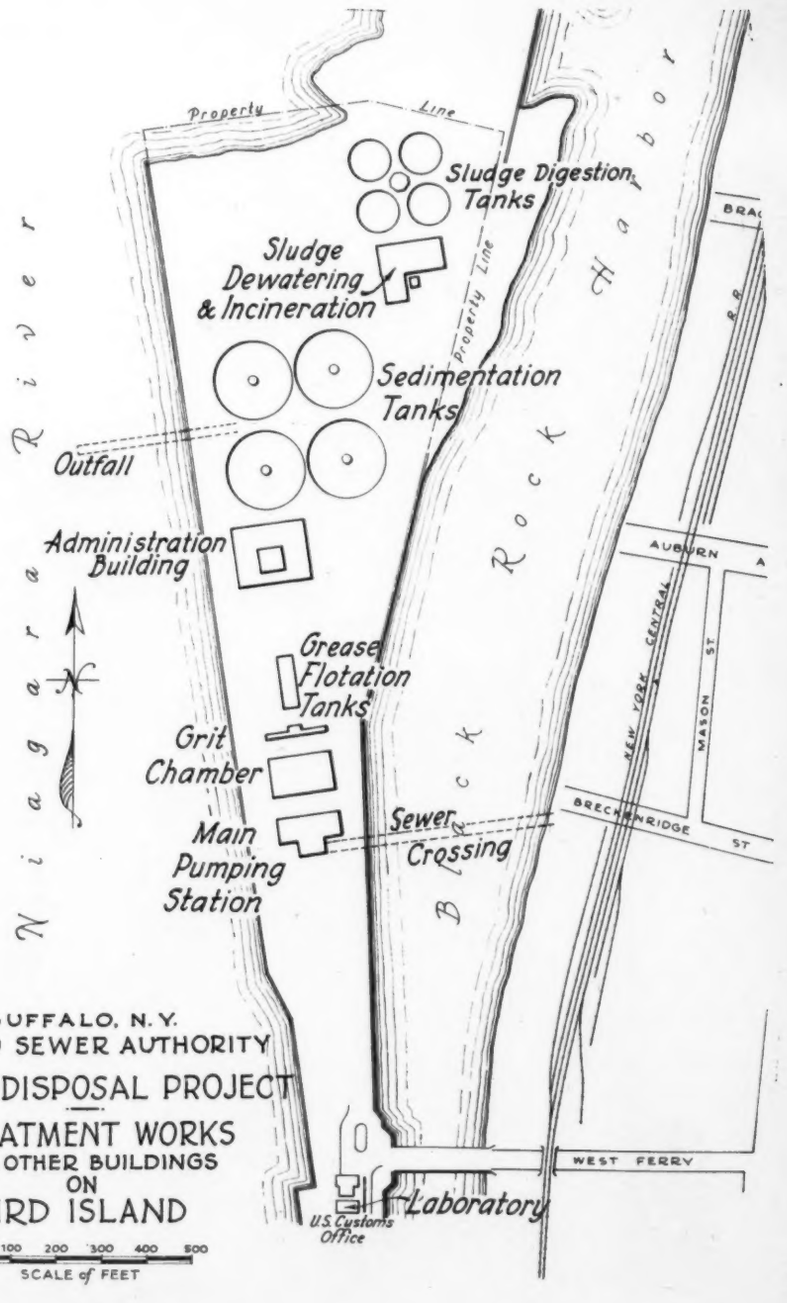
Sewage treatment comprises screening, grit removal, sedimentation, sterilization with chlorine and sludge disposal. Sludge disposal in turn will comprise partial digestion, mechanical dewatering and incineration. The design of the treatment works is for a population of



Buffalo Sewer Tunnel in Rock, Looking Through the Holing-Through Point

Buffalo Sewer Tunnel After Lining





General Plan, Buffalo Trunk Sewer System and Treatment Works Layout

Some of the Open Cut Construction

750,000. The arrangement is such as to permit expansion and the introduction of additional processes if and when such may become desirable—see plan showing general arrangement of units.

A temporary laboratory has been established on Bird Island for preliminary studies. This will be transferred to the treatment works and become the control and research laboratory for the completed works.

The so-called Bird Avenue relief sewers have a total length of about 3.6 miles. They vary in diameter from 42 inches to twelve feet. About 2.1 miles of the larger sizes are being constructed in rock tunnels and the remainder are constructed in open cut.

$10,200,000 for Sewers and Pump Station

In round numbers the construction costs of the main elements of the project will be as follows:

Intercepting sewers and appurtenances, including two local pumping stations	$ 7,000,000
Main pumping station	1,000,000
Treatment works	3,000,000
Bird Avenue relief sewers	2,200,000
Total	$13,200,000

On May 1st there had been awarded 22 contracts on all elements of the project. These contracts total in round numbers $10,700,000. Engineering work was started late in November, 1935. The first contract was awarded in December, 1935. The last of the major contracts will probably be awarded in July, 1937, and the entire work is scheduled to be completed by July, 1938.

An Old Canal Bed Came in Handy for a Concrete Pipe Section

The work is being done under the Buffalo Sewer Authority—Daniel H. McGarriagher, chairman, and Kevin Killeen, Henry W. Keitzel and Wm. M. Coon, members. The writer's firm is serving as engineers for the Authority, having charge of investigations, design and construction on intercepting sewers and appurtenances, pumping stations and treatment works. Geo. J. Summers, Commissioner of Public Works, is in charge of design and construction of Bird Avenue relief sewers, with the writer's firm serving as consultants on this project. Edward P. Lupfer is Directing Engineer for the Sewer Authority. The project is being financed with the aid of the Federal Administration of Public Works, for which Harold Epstein is Project Engineer and Earl L. Peterson is Chief of the Inspection Division.

▼

Vance Now Chief Engineer Louisville Water Works

Stuart Vance (Out-Maneuvered "Old Man River")

It is with much pleasure that we are privileged to record the fact that L. Stuart Vance has been promoted to the position of Chief Engineer of Water Works at Louisville, Ky.

Formerly Principal Assistant Engineer (Acting Chief Engineer, since the death of John Chambers), Mr. Vance, during the calamitous flood experiences which engulfed the main pumping station of Louisville's Water Works, had a chance "to win his spurs." He did—"the spurs" of a General. It was Vance, with his men licked in every quarter by the relentless charge of the swirling Ohio which had him cut off from land supplies and reserves by three-quarters of a mile of water, who out maneuvered "Old Man River" by commandeering a river-boat to recapture the temporarily lost pump station. On page 98 of our March issue the story of this strategic move is briefly told. The river boat, tied up to the pump station, became the source of steam to run an obsolete pump with main bearings under water. The decision and action which followed made water supply history of epic style. Naturally, it was not this alone which entitled Mr. Vance to the position won and deserved; but it was a keen piece of generalship which was exhibited.

Mr. Van is a native of Louisville. He was graduated by Cornell University in 1922 and chose water supply engineering as his profession, by immediately entering the Louisville Water Department under John Chambers. For some time prior to Mr. Chambers' death, Mr. Vance had been carrying the responsibilities and executing the duties of Chief Engineer, in the course of which he had full opportunity to demonstrate his ability to fill the position he now has been awarded. It comes to him on the basis of service and merit.

Louisville should in some lasting manner memorialize the services of its Water Supply Battalion and its chief who fought defiantly to keep water in the mains of a suffering community; and, in winning against a relentless river, came out rating Medals of Valor.

A. W. W. A.—*Presents*

Its Program for the 57th Annual Convention—Buffalo, N. Y.

THE following program has been released, subject to possible minor revisions, by L. H. Enslow, Chairman of A. W. W. A.'s Committee on Technical Program and Publications; W. S. Orchard, Chairman, Committee on Entertainment; H. E. Jordan, Secretary of the Association:

MAIN SESSION

MONDAY FORENOON—

9:30 Convention Opens—W. W. Hurlbut, presiding.
Reports of Committee Chairmen.
9:45 Transite Pipe—W. R. Knowles.
10:25 Gate Valves—G. Dale Dixon.
11:05 Fire Hydrants—Wm. R. Conard.
11:45 The President's Address—Wm. W. Hurlbut.
Luncheon Conference
12:30 Secretaries of A. W. W. A.'s Local Sections.

MAIN SESSION

(W. V. Weir, Chairman, P. M. & O. Div.)

MONDAY AFTERNOON—

2:00 The Water Works of Buffalo—Alan D. Drake.
2:40 Report of Com. on Laying of C. I. Pipe—Wm. C. Mabee.
3:00 Superintendents' "Round Table"—
(1) Discussion; Report on Laying of C. I. Pipe—T. J. Skinker, leader.
(2) Pipe Finding and Leak Location—S. F. Newkirk, leader.
(3) Reconditioning of Salvaged Pipe—R. J. Newsom, leader.
(4) Fixed Period Operation of Gate Valves—J. S. Dunwoody, leader.
(5) Methods of Repairing Pipe and Joint Leaks—W. V. Weir, leader.
(6) Diesel Power vs. Purchased Electric Power vs. Steam Power in Pumping Reliability and Costs.

PURIFICATION DIVISION

(C. J. Lauter, Chairman)

MONDAY AFTERNOON—

2:00 Committees' Reviews of Progress and Plans.
(1) Chlorine Ammonia Treatment—F. W. Gilcreas, Chairman.
(2) Determination of Fluorides—A. P. Black, Chairman.
2:30 Survey of the Condition of Rapid Sand Filter Beds in Illinois—C. W. Klassen. (H. E. Hudson, Discussion.)
3:10 Silicates as Aids to Coagulation—John R. Baylis.
(A. P. Black, S. T. Powell, O. M. Smith—Discussion.)
4:00 The Dynamics of Sedimentation—J. J. Slade.
Round Table Discussion of Sedimentation.
(Gordon Fair, L. V. Carpenter, M. E. Flentje, W. A. Sperry, A. S. Behrman.)

COMMITTEE MEETINGS AND CONFERENCES

(Open to all Association Members)

MONDAY AFTERNOON—

2:30 The Manual Committee of the Finance and Accounting Division—Hal F. Smith, Chm.
3:00 Conference. The Work of the American Research Committee on Grounding—M. W. Cowles, Chm.
4:45 Committee on Specifications and Tests for Powdered Activated Carbons—Mathew M. Braidech, Chm.
5:00 Water Works Practice Committee—Malcolm Pirnie, Chm.
(All matters to be brought before this committee should be presented to the chairman in advance.)

MONDAY EVENING—Dancing (Informal) and "Get-Together."

MAIN SESSION

(William W. Hurlbut, presiding)

TUESDAY FORENOON—

9:30 Twenty-five Years' Operation of the Los Angeles Aqueduct—J. E. Phillips.
10:10 International and Interstate Pollution Problems—J. K. Hoskins. (A. E. Berry, C. A. Holmquist, S. A. Greeley—Discussion.)
10:55 The Future of Water Allocation and Developments in Interstate Agreements—Duane Minard. (Discussion to be opened by Willard Chevalier.)
11:35 Review of the Work of the National Resources Committee and the Status of Anti-Pollution Legislation—Abel Wolman. (Discussion to be opened by F. H. Waring.)

FINANCE AND ACCOUNTING DIVISION

(Hal F. Smith, Chairman)

TUESDAY FORENOON—

9:30 The Value of a Manual of Accounting Procedure for Water Works—Carl H. Chatters.
10:15 The Preparation of a Manual of Accounting Procedure—Charles T. Sweeney.
11:00 Free Discussion Invited on the Plan.

12:30 Annual Luncheon. Finance and Accounting Div.
(All interested in the work of the Division are invited to attend.)

MAIN SESSION

(William W. Hurlbut, presiding)

TUESDAY AFTERNOON—

2:00 The Licensing of Water Works Operators.
Introduced by L. V. Carpenter, Chairman of Committee on Water Works Short Schools and Licensing.
Michigan Experiences—Edward D. Rich.
Texas Experiences—V. M. Ehlers.
New Jersey Experiences—Chas. H. Capen, Jr.
California Experiences—Ray F. Goudey.
A. W. W. A.'s Activity—L. V. Carpenter.
3:00 Retirement and Pensioning of Water Works Employees. The Effect of Federal Legislation on this Subject—Dale L. Maffitt, Chairman of Comm. on Social Security Legislation.
Municipal Activity—Leon A. Smith.
4:00 Records of Actual Water Demands in Air Conditioning—Leaders: L. D. Gayton, O. C. Holleran; W. C. Mabee.

PURIFICATION DIVISION

(C. J. Lauter, Chairman)

TUESDAY AFTERNOON—

2:00 See Main Session Program—of Interest to all Members.
3:00 Water Softening Symposium.
(1) Review of Lime Soda Softening—Chas. P. Hoover.
(2) The Conditioning of Softening Precipitates—Chas. H. Spaulding.
(3) Review of Zeolite Softening—S. T. Powell.
4:30 Discussion. (F. D. West, A. S. Behrman, F. H. Weed, E. W. Johnson.)

5:00 Panel Discussion—"How Are Public Water Supplies Related to the Incidence of Gastro Enteritis?"
This discussion is open to all who wish to take part. The following persons are among those who have indicated that they will have something to offer:
(A. E. Berry; W. L. Mallmann; John F. Norton; A. V. Hardy; N. R. Ziegler; J. J. Hinman, Jr.; George D. Norcom; F. H. Waring; Frank E. Hale.)

TUESDAY AFTERNOON—Ladies' Fashion Show.

TUESDAY EVENING—The All-Division Dinner and Floor Show.
(Master of Ceremonies—"Bill" Orchard)

JOINT SESSION

(William W. Hurlbut, presiding)

WEDNESDAY FORENOON—
Symposium on 1937 Floods, with Particular Reference to their Effects upon Water Works, the Rehabilitation and the Protective Measures for the Future.
9:30 Huntington, W. Va.—J. C. Crenshaw.
9:50 Cincinnati, Ohio—A. S. Hibbs.
10:10 Louisville, Ky.—L. S. Vance.
10:30 Evansville, Ind.—L. A. Geupel.

10:50 Cairo, Ill.—C. M. Roos.
11:10 London, Ontario—E. V. Buchanan.
11:30 Summation and General Aspects—L. R. Howson. (Discussion opened by W. W. DeBerard.)

COMMITTEE ON BOILER FEEDWATER
(C. H. Fellows, Chairman)

Wednesday Forenoon—

9:30 Report of the Activities of the Joint Research Committee on Boiler Feedwater Studies—C. H. Fellows, Chm.
10:15 Coagulation as Applied to Industrial Waters—A. P. Black, R. A. Bardwell, and B. W. Graham.
11:00 Removal of Dissolved Mineral Solids from Water by Organic Exchange Filters—P. G. Bird, W. Kirkpatrick, and Easton Melof.
11:45 A Study of Contemporary Zeolites—L. F. Collins.

Wednesday Afternoon—A. W. W. A. Excursion to Niagara Falls.

Wednesday (All Day)—Golf Tournament, Niagara Falls Club.

Wednesday Evening—Dinner-Dance, Cataract House, Canadian Falls. Special illumination of the Falls. Return to Buffalo about midnight.

MAIN SESSION
(William W. Hurlbut, Chairman)

Thursday Forenoon—

9:30 Motion Picture: Transite Pipe.
10:00 Work of the Boiler Feedwater Committee in Review—C. W. Fellows, Chm.
10:10 Review of Progress and Developments During Past Year:
(1) Reservoirs, Supply Lines, Pumping—L. R. Howson.
(2) Treatment and Purification—Paul Hansen.
10:40 Water Hammer and Its Control—S. Logan Kerr. (A. F. McQueen, V. C. Lischer, C. J. Des Baillets—Discussion.)
11:30 Small Sizes of Cast Iron Pipe—J. D. Sample.
12:00 Spiral Weld Steel Pipe—Russell Barnard.

FINANCE AND ACCOUNTING DIVISION
(D. C. Grobbel, presiding)

Thursday Forenoon—

9:30 Building and Retaining Customers' Good Will—H. L. Meites.
10:10 Activities of the Los Angeles Water Sales Division—Thad M. Erwin.
10:50 Internal Audit and Control—Paul D. Williams. (E. C. Schwier—Discussion.)
11:30 The Validity of the Water Charge Lien—Leo T. Parker.
12:10 Business Meeting.

PURIFICATION DIVISION
(C. J. Lauter, Chairman)

Thursday Forenoon—

9:30 Correlation of Bacterial Pollution with Watershed Population—E. Sherman Chase. (S. A. Greeley, E. S. Clark—Discussion.)
10:15 Experiences with Taste and Odor Removal at Hammond, Ind.—J. C. Vaughn. (P. L. McLaughlin—Discussion.)
11:00 A Simplified Method of Iron and Manganese Removal—D. L. Erickson.
(N. T. Veatch, Jr.—Discussion.)
11:45 Experiences With "Anthrafilt" in a Slow Sand Filter—A. C. Bailey. (H. G. Turner—Discussion.)

Thursday Noon—Bridge-Luncheon for the Ladies.

JOINT SESSION
President-Elect Eugene F. Dugger, presiding)

Thursday Afternoon—

2:00 Corrosion Control—Chas. P. Hoover. (J. R. Baylis, G. D. Norcom, M. E. Flentje, S. T. Powell—Discussion.)
2:45 Air Conditioning and Its Bearing on the Cross Connection Problem—F. M. Dawson and A. A. Kalinske. (Chas. R. Cox—Discussion.)
3:15 Round Table—Organization and Preparation of Water Works to Meet Major Catastrophes:
(1) Floods—E. A. Munyan.
(2) Conflagrations—H. E. Halpin.
(3) Earthquakes—N. A. Eckart.

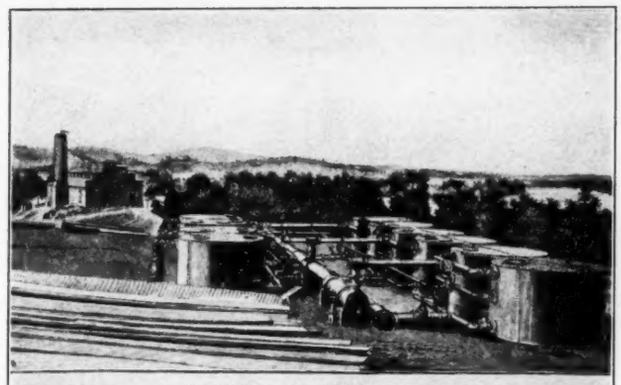
Thursday Evening — The Annual Banquet — Floor Show — Dancing — Presentation of Awards and Honorary Memberships. *"Auld Lang Syne"*

76 A. W. W. A. Exhibits Planned

To the date of this writing the following 76 firms had exhausted the available exhibit space and late-comers were having to share booth space with others willing to do so. The 76 exhibitors compare with 60 at the 1936 convention:

1. Activated Alum Corp.
2. The American Brass Co.
3. American Cast Iron Pipe Co.
4. American City.
5. The American Rolling Mill Co.
6. The Atlas Mineral Products Co. of Pennsylvania.
7. Badger Meter Mfg. Co.
8. The Barrett Co.
9. Bingham & Taylor Corp.
10. Birch Mfg. Co.
11. Buffalo Meter Co.
12. Builders Iron Foundry.
13. Carson-Cadillac Corp.
14. The Central Foundry Co.
15. The Chapman Valve Mfg. Co.
16. Chicago Bridge & Iron Works.
17. Crane Co.
18. Darco Corporation.
19. Darling Valve & Mfg. Co.
20. DeLaval Steam Turbine Co.
21. The Dorr Co., Inc.
22. S. R. Dresser Mfg. Co.
23. Eddy Valve Co.
24. The Edson Corporation.
25. Engineering News-Record.
26. Fairbanks, Morse & Co.
27. The Farnan Brass Works Co.
28. Ford Meter Box Co.
29. The Foxboro Co.
30. The Fred W. Hanks Co.
31. Michael Hayman & Co., Inc.
32. Hays Manufacturing Co.
33. Hersey Manufacturing Co.
34. Homelite Corporation.
35. Hydraulic Development Corp.
36. Industrial Chemical Sales Co.
37. International Filter Co.
38. Johns-Manville.
39. The Kennedy Valve Mfg. Co.
40. Koppers Co., Western Gas Div.
41. The Leadite Company.
42. Lead Lined Iron Pipe Co.
43. Lock Joint Pipe Co.
44. The Ludlow Valve Mfg. Co.
45. McWane Cast Iron Pipe Co.
46. Merrimac Chemical Co.
47. M & H Valve & Fittings Co.
48. Mueller Co.
49. National Meter Co.
50. National Water Main Cleaning Co.
51. Neptune Meter Co.
52. The Pardee Engineering Co.
53. Phoenix Meter Corp.
54. The Pitometer Co.
55. Pittsburgh-Des Moines Steel Co.
56. Pittsburgh-Equitable Meter Co.
57. Reilly Tar & Chemical Corp.
58. Rensselaer Valve Co.
59. Ross Valve Mfg. Co., Inc.
60. L. A. Salomon & Bro.
61. Simplex Valve & Meter Co.
62. The A. P. Smith Mfg. Co.
63. S. Morgan Smith Co.
64. R. S. Sparling.
65. Syntrom Company.
66. Thomson Meter Co.
67. United States Pipe & Fdy. Co.
68. United States Steel Corp. Subsidiaries.
69. Wailes-Dove-Hermison.
70. Wallace & Tiernan Co., Inc.
71. Water Leak Detector Co.
72. Water Works Engineering.
73. Public Works Magazine.
74. R. D. Wood Company.
75. Worthington-Gamon Meter Co.
76. Water Works and Sewerage.

This Picture, from an Old Wood Cut, Is Chattanooga's First Filter Plant (3 M.G.D.) Installed in 1888, One Year Later Than Atlanta's Plant, Which Was the First "Mechanical" Plant of Any Size in America. "Believe It or Not!" These Early National Filter Company's Units Were Equipped With a Surface Water-Wash Grid and the Company's Featured Claim Was "Increased Economy by Surface Washing." These Units Are Still Held as "Standbys" at Chattanooga, Where Three Stages of Filter Evolution Are Represented.



NATIONAL FILTER PLANT.
CHATTANOOGA, TENNESSEE.

SOUTHEASTERN AND KY.-TENN. SECTIONS HOLD JOINT MEETING

IN CHATTANOOGA, Tenn., the Southeastern and the Kentucky-Tennessee Sections of the American Water Works Association held their first joint meeting April 5th, 6th, and 7th. With an attendance above the 300 mark, the official registration was 260 exclusive of the ladies attending.

The convention was opened with an address of welcome by acting Mayor and Commissioner of Fire and Police Eugene Bryant, who had several nice things to say about Al. Porzelius and his Chattanooga Water Company.

Entertainment, which was of a high order of quality, involved trips to the several points of historic interest around Chattanooga and dinner and bridge party for the ladies, a stag dinner for the men, and the final dinner and dance, with a well above the average floor show, closed the festivities. The convention closed with a golf tournament arranged by Al. Porzelius.

Retiring Chairman, Southeastern Section, J. E. Jagger, Birmingham, Ala.

Incoming Chairman, Southeastern Section, D. Rhett Pringle, Thomasville, Ga.

Retiring Chairman, Kentucky-Tennessee Section, Roy J. Morton, Nashville, Tenn.

Incoming Chairman, Kentucky-Tennessee Section, E. E. Jacobson, Lexington, Ky.

Officers 1937-'38

In separate business sessions, the following officers were named for the year ensuing.

Southeastern Section:

Chairman—D. Rhett Pringle, Supt. of Water Works, Thomasville, Ga.

Vice-Chairman—C. P. Townsend, Supt. of Water & Light, Abbeyville, S. C.

Secy.-Treas.—W. H. Weir, State Dept. Health, Atlanta, Ga.

Trustees—F. G. Crowe, Supt. Water Works, Florence, Ala.; J. L. Hawkins, Supt. Water Works, Greenville, S. C.; M. G. Stewart, Supt. Water Works, Natchez, Miss.; T. E. P. Woodward, Supt. Water Commission, Macon, Ga.

Member of A.W.W.A. Board of Direction—J. K. Marquis, Engr. of Filtration, Water Department, Spartanburg, S. C. [W. H. Weir continues as Director through the 1937 convention in June.—Ed.]

Kentucky-Tennessee Section:

Chairman—E. E. Jacobson, Chief Engr. Water Works, Lexington, Ky.

Vice-Chairman—C. M. McCord, Gen. Supt. Water Dept., Memphis, Tenn.

Secy.-Treas.—H. D. Schmidt, State Dept. Health, Nashville, Tenn.

Trustees—Hall Arnold, Supt. Water and Light, Madisonville, Ky.; H. C. Bristol, Supt. Water Dept., Alcoa, Tenn.

Member of A.W.W.A. Board of Direction—J. J. Quinn, Supt. Filtration, Knoxville, Tenn. [Mr. Quinn's term continues until 1938.—Ed.]

A. W. W. A. Directors

Kentucky-Tennessee—J. J. Quinn, Supt. Filter, Knoxville, Tenn.; Southeastern—J. K. Marquis, Filter Engr., Spartanburg, S. C.; Southeastern—W. H. Weir, State Department Health, Atlanta. *Mr. Marquis Is Director-Elect to Succeed Mr. Weir in June.*

President Hurlbut Attends

W. W. Hurlbut, President of A.W.W.A., came on from Los Angeles to tell A.W.W.A. members attending the Florida Section and this meeting of the noteworthy progress being made by the Association under Jordan's leadership as Secretary, since the first of the year. To his mind one of the most important phases of association work was the encouraging of operator licensing movements, which looked to the raising of qualifications and insurance of security of operators. He commented on the innovations in improvement of the Journal, the forthcoming committee reports to appear therein during the year and others to appear in the form of a series of separate monographs. He outlined the several advantages derived from membership in A.W.W.A., now showing signs of a renewed healthy growth.

Mr. Hurlbut then delivered an illustrated running talk covering the highly interesting history of **"The Water Supply System of Los Angeles,"** which had several times suffered "growing pains" due to necessarily rapid expansions. For 30 years operated as a privately owned water company, the system was bought by Los Angeles in 1902. A consumption of 300 gals. per capita, when taken over, had been successfully curtailed by metering. Today, 100 per cent metered, the consumption was still 119 gals. per capita, due to irrigation usage and lawn sprinkling in what would otherwise remain the desert Pueblo of Los Angeles, as it was chartered by the King of Spain in 1781. From the early sub-surface flows of the Los Angeles River to the melting snows of the 14,000 ft. high Sierras had the "City of the Angels" gone with its one time "dream aqueduct" of 238 miles, 54 miles being mountain tunnel delivering to canyon syphons under 868 ft. of head. As an auxiliary, 200 wells had been put down in the Los Angeles River Valley and the latest addition was the now constructing Mono Lake Project. Mr. Hurlbut explained that its present reservoir system comprised 19 major supply reservoirs and 45 distribution reservoirs or tanks. The distribution system, covering 450 sq. miles, boasted 3,940 miles of mains fed by 13 major trunk lines—one being under 325 lbs. pressure. That Los Angeles did not intend to go thirsty, its share of the waters to be diverted from the Colorado River was 82 per cent—if, and when, needed and paid for as a security measure principally.

Especially noteworthy was the use of otherwise obsolete employees on an intensive 9-year program of landscaping and beautification of water works properties. Also interesting was the fact that for main sizes above 24-inch steel pipe was used, whereas in the grid system only cast iron pipe was employed. The ability of the latter to stand up under earthquake stresses was ascribed to the large factor of safety provided through use of class 250 pipes. Another item of interest was the fact that the Water Works owns and operates its own bituminous pipe coating plant and through its testing laboratories had been instrumental in development of improved primers, coatings and linings.

Technical Sessions

Chairman—J. E. Jagger, Southeastern Section.

Chairman—Roy J. Morton, Kentucky-Tennessee Section.

(Each serving as the presiding officer at alternate sessions.)

"Public Safety in Water Works Operation," by T. W. COLEMAN, Resident Engineer, City Water Company, Chattanooga, Tenn.

In discussing the various hazards to the safety of the general public in water works operation and its structures, Mr. Coleman stressed meter and curb boxes as the greatest hazard. In Chattanooga, with 27,000 meter-box installations, 300 claims or suits for injuries during a 10-year period had made it essential in 1927 to study and correct the sidewalk meter-box hazard, responsible for injuries from tripping and falling. That year the company established its Public Safety Committee, which studies and corrects hazards and presents facts and methods of correction before regular safety meetings of department heads, foremen, and employees. Success had been attested by a reduction of the average number of accidents per year from 40 to 3, with none to date in 1937.

Some of the methods employed in securing such accident reductions were related by Mr. Coleman. Among the more important had been the schooling of meter readers and helpers (aided by moving pictures) in reporting defective meter boxes; the accurate reporting of even minor defects by readers monthly; resultant prompt correction or repairs now totaling 28,000 correction orders. For possible use in defeating damage suits, careful condition records had been kept and frequently pictures are made promptly upon receiving a report of an accident. As a possible future witness for the water utility the consumer served by the meter-box has an excellent standing in court to combat fraudulent claims

Kentucky-Tennessee Officers

Trustee—Hall Arnold, Supt. Water, Madisonville, Ky.; Vice-Chairman—C. M. McCord, Supt. Water Dept., Memphis, Tenn.; Sec.-Treas.—H. D. Schmidt, State Dept. Health, Nashville, Tenn.

or to prove negligence on the part of the plaintiff, if actually injured. Aside from preventing fraudulent claims, the careful and prompt investigation to establish reasonableness of damage claims had resulted in equitable settlements out of court, to the decided advantage to all concerned.

Mr. Coleman emphasized as the second most important factor in public safety, that of carefully selecting and schooling drivers of utility automotive equipment. During 1936 his company had operated 8 service trucks over the city without an accident, but all drivers had been selected with care and drilled as to what to do in case of an accident. In connection with open trench in busy sections a watchman was kept on night duty in addition to the liberal use of red lanterns and barricading.

"Some Problems Confronting Water Works Officials in the Control of Water Borne Disease," by F. W. KITTRELL, Asso. Engr., State Dept. of Health, Nashville, Tenn.

Mr. Kittrell's paper dealt with the matter of recurrent outbreaks of gastro-intestinal disturbances which pointed suspiciously, if not with reasonable certainty, to water supply as the source. Four cases in Tennessee during the past three years, involving unusual conditions, were cited. Many questions which had come up during investigations had not been answered, but were presented merely as "food for thought" without divulging the names of the communities involved. In one instance, by a set of coincidences, a deep well supply to 9,000 people in West Tennessee (long considered safe without chlorination) had been responsible for water borne outbreak of 3,000 cases of diarrhea traced to a failure which "never could happen," but actually did. In another case visitors to the community "Beta" suffered from diarrhea, whereas natives were apparently immune. First assumed to be due to chemical constituents of the water, examinations disproved such. In the end it was traced to inefficient chlorination control on a limestone area polluted spring water. The unanswered question—"Why the immunity of the natives?" In the town of "Gamma" repeating "week-end" occurrences of intestinal disturbances had been persistently reported. Warranting an investigation, many assumed possibilities were exhausted. There were apparently no cross connection hazards or deficiencies in chlorination control, until it was discovered that gradual lowering of reservoir head during the week resulted in a 75-lb. pressure on the pumps on Mondays dropping off to 70 lbs. on each Friday. By test the assumedly constant output pumps delivered 260 g.p.m. against 75 lbs. and the fixed chlorine dosage proved adequate. On Fridays, however, the pumps against the 70-lb. pressure delivered 315 g.p.m. (21.2% more water against 5 lbs. less head) and the result was a less effective disinfection toward the end of each week.

Southeastern Trustees

T. E. P. Woodward, Supt. Water Works, Macon, Ga.; Frank G. Crow, Mgr. Water Dept., Florence, Ala.; J. L. Hawkins, Supt. Water Works, Greenville, S. C.

The important "nigger in the wood-pile," however, proved to be a leaking sewer in the limestone formation, the correction of which stopped diarrhea from spending week-ends in "Gamma." The failure, however, to be able to correlate the low coli-aerogenes counts on the distribution system with the recurring disturbance, is still one of those open questions which constitute food for thought.

Another case cited by Mr. Kittrell proved the difficulty in effectively sterilizing mains once they had been filled with polluted water. A chlorine residual of 3 parts at the flushed fire hydrants failed to kill all coli-aerogenes in the mains, and these returned upon lowering the residual to 0.5 parts at the plant. Especially was the return of the organisms noted earliest on the fringes of the system. A second program of more intensive flushing with water containing 3 parts of residual was required to eliminate the trouble. Most interestingly, commented Mr. Kittrell, not one complaint regarding taste was received during the period when 3 parts of chlorine were maintained for two weeks, and for five days more in the second attack.

In discussion, MR. DEJARNETTE (Georgia Dept. of Health) related other experiences in which the cause of dysentery outbreaks had not been satisfactorily identified. A. E. GRIFFIN (Wallace and Tiernan Co.) told of a disturbance apparently due to organic matter decomposition in the storage tanks and filters on the cruise ship Rotterdam, which chlorination had at least partially corrected. W. W. BRUSH said that since New York City had resorted to chlorination of its supplies at two or more points (four chlorination points on some supplies) intestinal disturbances had progressively decreased over the past several years. L. H. ENSLOW said that this matter of unexplained gastro-intestinal disturbances had reached a point demanding such consideration as to warrant an open informal discussion on it, as scheduled for the 1937 A.W.W.A. Convention. Such would probably lead to the establishment of a committee to look searchingly into the matter, with hopes of arriving at some concrete solution of the problem. MR. KITTRELL, in reply to a question, pointed out the possibility of a relationship between bad tastes or odors and high bacterial growths found frequently in dead ends, and intestinal disturbances.

Al. F. Porzelius, Mgr., City Water Co., Chattanooga (Host to the Convention); Had Everything Fixed with the Police Commissioner —Just in Case!

Miss Lois Sutherland, Treas., Paducah, Ky., Water Dpet. (For the First Time in 53 Years She Saw Her Plant Shut Down. For 25 Days It Was Out.)

"Sanitary Protection of Public Water Supplies," by A. E. GRIFFIN, Research Chemist, Wallace and Tiernan Co., Newark, N. J.

Mr. Griffin discussed the matter of storage and watershed protection vs. dependable purification, as methods of safeguarding water supplies. Citing the advantages

Homer G. Turner, Engr. Anthracite Institute, New York City; W. H. Lovejoy, Supt. Filtration, Louisville, Ky.; W. A. Welch, "Nuchar" Sales Engr., Chicago, Ill.

and extended safety from multiple chlorination such as practiced on the New York supplies, he also noted that since all feeder streams of the Wanaque Reservoir of the North Jersey Water Supply District had been chlorinated the reservoir water ahead of the secondary automatic (effluent) chlorine-ammonia treatment had passed U. S. Public Health Standards 90 per cent of the time. (The chlorine is applied first at Wanaque and the ammonia thereafter to "fix" the residual chlorine entering the supply main and system.—Ed.)

Mr. Griffin said that more operators were becoming convinced of the values to be had from pre-chlorination as an unequalled safety measure, in addition to otherwise improved or more economical plant operation. In dead ends after-growths occurred in the slime and accumulated deposits. On this account and to protect against reservoir contamination and minor cross-connection hazards, residual chlorine in the mains, to the far corners, was becoming more general practice. In that direction ammonia-chlorine treatment possessed distinctive advantages. If there was any single formula applicable to chlorination in filter plant practice, it seemed to be pre-chlorination, in conjunction with carbon treatment if necessary, and ammonia-chlorine treatment of the plant effluent.

PAUL WEIR (Atlanta, Ga.) agreed with Mr. Griffin on his evaluation of pre-chlorination. With 14 hours of contact in the Atlanta coagulating basin, the ammonia-chlorine application to the raw water maintained sterile basin and filter conditions. Residual chlorine of 0.25 was maintained in the water to the filters, the beds were kept clean and most of the residual passed through. In the mains 0.2 parts residual was being maintained. To have 14 hours of sterilized water ahead of the filters was a great asset in case there should be purification failures for short periods.

In the discussion and questioning which followed, it was developed that a higher residual was requisite when using ammonia—to do the same job in the same time, about twice as much residual. For quick bacterial kill it would in many cases prove feasible to add the chlorine first and the ammonia thereafter to "fix" the residual for long carriage through the system. Due to increasing air conditioning, involving use of cooling water from private sources of supply, the cross-connection leak problem was intensified and seemed an added reason for having residual chlorine in the mains.

"The Chemical Character of Natural Waters," by W. L. LAMAR, Chemist, U. S. Geological Survey, Atlanta, Ga.

Employing the very interesting graphical color combination charts devised by W. D. Collins of the U.S. G.S., Mr. Lamar gave a pictorial presentation of what constitutes "good and bad" waters, and the combinations of base and acid radicles which determined hardness, corrosiveness, etc. He pictured the marked difference in water quality with stream flow changes and, thereby, emphasized the need for many analyses of a stream supply before the truth as to the water quality of such could be truthfully known. Concerning almost parallel streams (3 miles apart) a marked difference in water quality had been found, thus indicating the dangers of assumptions based on geography rather than geology. In storing water samples only the best flint glass should be used, since soft glass gave up alkali to the water. Likewise a stored water sample, containing mud, would gradually dissolve compounds from the mud and give misleading analytical results. In the latter, biological activity was a factor.

In discussion, L. H. ENSLOW told of the interesting theory applied to explain the very soft water, high in sodium bicarbonate, taken from deep wells in Dallas and Fort Worth, Texas. It was a fact that the rain entering the soil of West Texas gathered considerable hardness in joining the ground waters. The hard ground water flow toward the coast apparently exchanged its calcium and magnesium for sodium in passing through great beds of natural zeolite sands known to exist in Texas. The net result was a natural and completely softened water when intercepted at Dallas, some of the wells being originally flowing ones. The product was what might be called a "slick" water and washing out soap in laundrying with it was difficult, as was de-soaping in bathing in it.

Novel Water Supply

"The Birmingham Industrial Water Supply," by A. CLINTON DECKER, Sanitary Engineer, Tennessee Coal and Iron R. R. Co., Birmingham, Ala.

Mr. Decker, a member of the Engineering Commission for the Birmingham Industrial Water Supply, described their unique municipal project, now under construction, to provide abundant water for industrial purposes and creation, thereby, of a new horizon for in-

Paul Weir, Filter Superintendent, Atlanta, Georgia. (Round Table Leader).

Tom Wolfe, Engr.-Mgr. Cast Iron Pipe Research Assn. (Round Table Leader).

dustrial growth now limited due to water supply deficiencies.

Made possible through a joint loan from PWA and grant from WPA, the project, to cost almost $6,000,000, consists of an impounding reservoir of 21 billion gals. capacity formed by a rock-fill dam; 44 miles of supply

and distribution mains (16 to 60 in. diam.); a 65 m.g. distribution reservoir on the outskirts of the city; a plant for chlorination and correction of corrosiveness with lime. The 16-mile supply main, from the impounding reservoir, had involved the use of 86,000 ft. of 60-inch welded steel pipe (wall thickness 3/16 in.) protected with a spun lining and coating of coal-tar base "Bitumastic" enamel and jointed with sleeve-type Dresser Couplings. Steel pipe in sizes down to 42-inch had been selected after alternate bids taken on cast-iron and steel of this size had shown the latter less costly. Fabricated locally by Chicago Bridge and Iron Works and Ingalls Iron Works Company, most of the pipes were 48 feet in length—the longest ever used on a major water supply project. In the distribution system all pipes smaller than 42-in. were of cast-iron.

The rock-fill dam, with clay face, is to be 1,100 ft. long at the crest and 195 ft. high, with a base 1,000 ft. thick. The working spillway was to be of the morning-glory drop-shaft type. An emergency spillway, consisting of a concrete weir on top of which is the 10-ft. earth "fuse-plug," is also provided as a safety precaution. The dam was let to contract (Walsh Construction Company, Davenport, Ia.) for $1,685,000. Incorporated was a $400 per day penalty or bonus clause if completed sooner or later than March 19, 1938—the bonus limit being $36,000.

Just below the close in distribution reservoir a chemical treatment plant will be equipped to super-chlorinate the water to discourage factory workers from drinking it. Also, to protect them in case they do. The water, being low in hardness and pH value, and liable to set up corrosion difficulties, lime treatment to boost the pH value, automatically controlled with a Leeds-Northrup potentiometer, is being provided.

Mr. Decker said that the three-member Industrial Water Supply Engineering Commission consisted of O. G. Thurlow, as Chairman, and J. D. Webb, City Engineer of Birmingham, in addition to himself. As Executive Engineer, in charge of design and construction, A. C. Polk had served from the beginning. He acknowledged the valuable contribution of 28 miles of right-of-way alongside of the L. & N. Railway, at the cost of but $1.00. After his paper, Mr. Decker gave a running account of construction progress as pictured by movie film.

Had Charge of Entertainment

Tom McCreery, U. S. Pipe Company, Birmingham; Gerry Kavanagh, Wallace & Tiernan Co., Knoxville; W. D. Taulman, Simplex Valve and Meter Co., Atlanta.

In reply to questions, he said that careful and interesting soil surveys had disclosed "hot spots" through which clay-blanketing of the pipe had been used to doubly insure against soil corrosion. From the pipe line, electric leads to the ground surface were being installed in order to detect current on the mains in the future.

L. H. ENSLOW said that, to his knowledge, the establishment of an industrial supply by a municipality was new and a significant development in American water supply practice. He wondered if there was any precedent. An interesting phase of the super-chlorination scheme had a value in industrial use of water which,

B. E. Payne, Supt. Pumping Station, Louisville; T. W. Coleman, Engr. City Water Co., Chattanooga; Clinton Decker, Engr. T. C. I. & Ry. Co., Birmingham.

possibly, the planners had not anticipated. He referred to the modern practice of condenser water chlorination to eliminate "slime" growths on tubes and, by improved heat transfer, insure a higher vacuum and worth while fuel economies, justifying the expense of chlorination. As to the possibility of cumulative current traveling along the main, he had always been under the impression that the rubber gasketed Dresser Couplings had a value in insulating one section of main from another.

Concerning municipally owned industrial supply, someone stated that Paterson, N. J., had installed what is known as the "Dyer's Pipe Line" and Charleston, S. C., was just completing a pipe line and plant additions for the sole purpose of supplying a new paper mill. Neither could be considered a parallel to the special six million dollar Birmingham Industrial Supply, divorced from the domestic public supply.

(If there be anything approaching or paralleling the Birmingham project in America, or elsewhere, we would like to hear something of it from our readers.—Ed.)

"Removal of Organic Detritus by Absorbent Clays," by DR. E. M. SLOCUM, Research Chemist, General Reduction Co., Macon, Ga.

Dr. Slocum pointed out that a matter of great concern to the filter plant manager were the soluble and colloidal materials which are not amenable to removal by simple coagulation. Aside from being the direct source of tastes and odors, such residues in coagulated water created filter bed gumming and mud balls, bacterial after-growths in mains, tastes and incidentally corrosion, due to putrefaction in dead ends. He then discussed the properties of adsorption possessed by certain clays or hydrated silicates. Especially effective were these clays in adsorbing aromatic oils such as given up by disintegrating algae and other products of organic degredation. The saturated clay particles then served as nuclei in floc formation, resulting in an indirect process of coagulation out of soluble and colloidal impurities. The most pernicious factor in filtration, in Dr. Slocum's mind, was the putrefying sludge depositions which yielded up its soluble decay end-products to contaminate the fresh incoming water above.

Concerning the value of certain processed clays (referred to as "Monterillinites") in aiding coagulation and lengthening filter runs, he cited cases wherein 10 lbs. of the clay to each million gallons of raw water had reduced turbidities on the filters from 25 parts to 5 parts per million. In the doctor's opinion there was some-

thing to say for powdered carbon added at the filters, in combination with clay pre-treatment to adsorb oily products, improve coagulation, reduce residual organic matter, and chlorine demand. In conjunction with raw water chlorination the clay actually adsorbed and carried chlorine down to the sludge zone, with beneficial

B. P. Rice, S. C. State Sanitary Engr., Columbia, S. C.; F. W. Kittrell, Engr. State Dept. of Health, Nashville, Tenn.; L. M. Clarkson, Georgia Sanitary Engr., Atlanta.

effect. Dr. Slocum closed by emphasizing the importance of proper processing in the production of absorbent clays and the selection of clays free of calcium carbonate.

In a written discussion, Mr. Gray, Chemist, Thomasville, Ga., reported that in water softening at Thomasville, the use of clay had resulted in a marked increase in magnesia removal (about 50 per cent), a consequent improved precipitation and increased removal of hardness, due to better clarification ahead of the re-carbonation stage. In addition, there had been noted longer filter runs. A saving in treatment costs of $3.00 per m.g. had been experienced.

Filtration and Filter Materials

"Comparison of Filter Bed Materials," by H. G. TURNER, Research Engineer, Anthracite Institute, State College, Pa., and H. W. SCHUMPERT, Supt. Water Works, Newberry, S. C.

Mr. Schumpert was called on to introduce this topic by relating his experiences with crushed anthracite "Anthrafilt" as a filter media. Having first used the material in a swimming pool filter, having limited washing facilities, it was seen to have merit and resulted in replacing the sand in one of the units of the Newberry Filter Plant. The ensuing experiences warranted full acceptance. The cost had been practically the same as if new sand had been purchased.

"Anthrafilt," although twice the cost of sand per ton, in having twice the bulk made both equal on a volume basis. In length of filter runs, the "Anthrafilt" had averaged 75 hrs. against 57 hrs. for the sand unit; maximum run, 167 hrs. against 91 hrs. for sand. Wash water 0.9 per cent against 1.13 for sand.

In reply to questions, Mr Schumpert said that 18 in. wash rise was equal to 24 inches with sand. The upper limit, without washing over some anthrafilt, seemed to be about 21 inches. The bed depth was 30 inches and there seemed to be no accumulation of mud coating on the anthracite. For breaking up hard spots or mud balls, Mr. Schumpert described a hand operated portable "Lightning" Stirrer, with a spiked cylinder of wood on the end of the motor driven shaft. By thrusting the "business end" into the partly floated bed a mud-ball never had a chance to grow into a hard-spot.

Mr. Turner followed with an informal discussion of theory vs. practice in filtration, which, with his random observations in visiting numerous plants, proved to be a high-light of the meeting. Adept with chalk and blackboard, he had no justification for apologizing for being "part professor-part peddler." In discussing filter washing, it was his observation that high velocity wash was neither as practical, economical, or as effective, as low water rates assisted by mechanical agitation. Scrubbing with surface wash jets or air wash preceding a low velocity water flotation produced, in effect, a rinsing of the already scrubbed filter bed grains. Perfection of the once frowned upon air wash system, if properly operated, had much to commend it if observations in glass filters were any criterion. A clean grain filter bed was certainly an operator's delight and an operating asset—theories, as to the value of a "schmutchdecke," notwithstanding. To make the water "rinse" most effective, with least cost, a filter bed level as close to the bottom of wash troughs as permissible had proved very helpful in the dirt kick-over, as opposing the dropping back of the larger flakes of floc to start mud balls.

In discussing the work of filters vs. coagulating basins, Mr. Turner said that the latter (costing 25 per cent as against 75 per cent for the filters) did almost 85 per cent of the work. This was too much like conditions in real life—the higher the pay the less the work done. The costly filter could and should be made to earn its keep more adequately by doing more work. That meant a new consideration, and why not the stepping up filtration rates beyond the 2 gal./sq.ft./min. which had been passed down from father to son to become more historical than scientific, but which we stuck to. As to the matter of size of filter media gains, Mr. Turner reviewed some of the findings of the A.S.C.E. Committee on Filtering Materials showing the economy and effectiveness of coarse grained media in deeper beds (30 in. or more) than fine grained media in shallower beds (24 in. or less). In comparing "Anthrafilt" with sands, he had found the flat grained anthracite of 0.6 m.m. size to equal in filtering performance sands of 0.38 m.m. size. He offered no theory to prove why, but was content with actual observed effects, involving cleaner beds, less shrinkage, higher permissible filtration rates, less mud accumulations, less wash water. Why one should adhere to the empirical 2 gal. rate per square foot, with modern raw water preparation, needed clarification. Especially so when realizing that several plants using anthracite as the media were producing satisfactory effluents at 100 to 200 per cent higher rates.

From "Ole Miss."

O. L. Sparks, Supt. Water and Light, Tupelo, Miss.; J. H. Miller, Chief Engr. Water Dept., Laurel, Minn.; Russell R. Miller, Supt. Water and Light, Amory, Miss.

In discussing filter bottom designs, the false bottom seemed to be the most satisfactory. The most intriguing was the Aloxite porous-plate (over a false bottom) recently offered with the idea of eliminating the gravel bed and getting good distribution without possibility of bed

inversion. Further than that, air alone, water alone or both together could be applied without fear of what may happen to the filter bed, since there were no gravel to mix up with the filtering material.

PAUL WEIR (Atlanta), said that in his experience it was not feasible nor practical to run much above 2 g.p.m. 1 sq. ft. rate with sand and that anthracite seemed to be the answer to stepping up filter rates. The porous grid bottom had a definite appeal.

(A further discussion of filter materials is to be found under the Round Table topic—"Filter Plant Operation." —Ed.)

1. Arthur Akers, of "Public Works"; 2. H. C. Erwin, Hersey Meter Co.; 3. J. L. Hodgson, A. P. Smith Mfg. Co. and National Water Main Cleaning Co.; 4. S. C. Hamilton, Chicago Bridge & Iron Works; 5. R. E. Ferguson, Hersey Meter Co.; 6. R. W. Ockershausen, Genl. Chemical Co.; 7. Everett M. Jones, Simplex Valve & Meter Co.; 8. Guy C. Northrop, Hydraulic Development Corp.

"Licensing of Water Works Operators," by W. W. BRUSH, Editor, "Water Works Engineering," New York City.

Mr. Brush, as a member of A.W.W.A.'s Committee on Operator Licensing, reviewed the recommendations of this committee headed by Professor L. V. Carpenter. In the report Class 1, 2, and 3 Operators had been defined, the criterion being educational qualifications in conjunction with and substituting in part for experience. Mr. Brush explained that it would be A.W.W.A.'s policy to aid rather than direct Sections in licensing matters, but that each must act as it believes best for its own good and that of its operators. For instance, Texas had chosen to continue with its voluntary licensing and the build up of the operator from a lower to next higher grade. Already 500 licenses had been issued in Texas and city officials had been kept informed of the operator's prowess. More recently the California Section had started a similar voluntary licensing scheme (110 licenses issued to date) preparatory to efforts directed toward securing compulsory licensing. In reply to a question, Mr. Brush said that a special licensing law was not requisite in those states having "Rules and Regulations" of the State Department of Health which were sufficient to cover the matter.

L. H. ENSLOW said that experiences with operator licensing indicated that various methods of procedure would be found most suitable for various states and sections; but, in general, a Standard Licensing Procedure, such as the A.W.W.A. Committee on Licensing might set up, should prove a useful pattern and profitable guide in the drafting of regulations or licensing acts. It seemed important to have licensing requirements so basically the same for various sections that operators licensed in one state would be capable of qualifying for a like position in another part of the country. As an illustration of what was meant, Mr. Enslow cited the recent receipt of a notice of examination for the position of Plant Superintendent at an important Michigan city. Certain qualifications were stipulated and ratings given each. Then as a closing reminder, in bold face type, was the all important statement to the effect that the applicant must meet those requirements for a Class "A" Operator, as prescribed in the Operator Licensing Laws of the State of Michigan. Without some standardization Michigan authorities might find it necessary to refuse to qualify an already licensed operator from some other state in which requirements in licensing lacked sufficient definition or stringency. Beginning with voluntary licensing was seemingly a good start for many sections and should serve to negative the effects of the undesirable "Grandfather Clause" which otherwise might be required in drafting a licensing act. After a few years of voluntary licensing strength would be thrown into efforts through legislatures to secure a stronger licensing act. To Mr. Enslow's mind legal status of licensing in the end would be essential if there be a real and permanent success of the movement, insofar as elimination of political interference and hazard to public health was concerned. In the meantime, voluntary licensing served well in the testing out period, and as an educational phase, to prove that nobody amounting to anything gets hurts in the process.

Objections to the advancement of operator licensing Mr. Enslow said, had been voiced by privately operated water companies because of a feeling that such state diction would disrupt organization or limit the supply of employables to a crippling and costly extent. In this connection, in West Virginia where many private companies operate, there had also been early fears. But, with the scheme followed in preparation for the licensing procedure (notably the short-school program and issuance of temporary licenses) there has been little or no dissatisfaction on the part of the private utilities. In fact, he had heard the best managers avow that it had materially helped their operation and had served to strengthen the worth while men and weed out inferior personnel to a mutual advantage of all concerned—except possibly the "weeds."

In South Carolina the plan of procedure was interesting. Only after 75 per cent of the operators have qualified under voluntary licensing requirements would there be an effort to secure a compulsory licensing law.

Flood Experiences

"Experiences in the Emergency Operation of the Louisville System During the Flood," were told in a lucid manner by B. E. PAYNE, Superintendent of Pumping Stations at Louisville. He told of sleepless hours in fighting off "Old Man River" and finally on Black Friday, January 22nd, losing in the end, with a marooned main pumping station separated from the main-land by ¾ mile of water. Then followed the battle of recapture by a never licked Chief Engineer—L. S. Vance—who called him out at 4:00 a. m. after the first few hours of sleep in several days, suggesting that a river boat be tied up to the station and hooked up to one of the old Allis-Chalmers steam pumps. With an "O. K. let's go!" he

Superintendents of Water

1. *Homer Schumpert (Newberry, S. C.)*; 2. *Sam Frye (Rome, Ga.)*; 3. *Frank Simmons (Russellville, Ky.)*; 4. *B. B. Ming (Winnsboro, S. C.)*; 5. *H. P. Powell, Supt. Water & Lgt., Griffin, Ga.*; 6. *Joe Clay (Carlisle, Ky.)*; 7. *Ed. Sweet (Birmingham, Ala., Water Works Co.)*.

told of the difficulties of locating needed steam hose from railroad shops under water, of maneuvering and hooking up the packet's steam boiler to the head of the pump, through acetylene welded header connections and 5 steam pressure hose lines, of the difficulties of getting the pump going with main bearings submerged and a repeatedly debris blocked fly wheel. Then of the manual operating difficulties (without steam governor), melting and bursting steam hoses; finally, the securing of flexible joints, and with the indispensable services of an expert acetylene welder of the making of fittings from pipe cut from radiators above water, putting in two 1½ inch steam lines which had to be heated at times by the same welder to prevent their snapping when the river started falling. Continuing to operate, with nothing but water lubrication of the submerged main bearing, for several days, at least, enough water for rationing was kept going to Lovejoy's filter plant located on high land. Mr. Payne's description was made doubly interesting with lantern slides while he lived it all over again.

"What Paducah Suffered," as related by MISS LOIS SUTHERLAND, Treasurer-Manager of Paducah's (Kentucky) Water Department, constituted a high-light of the program. In a well prepared and smartly presented account, Miss Sutherland told of the fight and abandonment of Paducah's 53-year old water plant, completely put out of service on January 24th for the first time in its history by a river stage 40 feet above normal which drove 32,000 of the 40,000 residents from their houses. Dewatering was undertaken with a deep-well turbine pump and only after 25 days of many vicissitudes had the filter plant and pump station been cleaned up gotten back into normal service and water with 3 parts residual chlorine turned in. With a depleted supply when the plant went under, 15-minute water rationing per day was kept up until numberless abandoned submerged faucets left open made it necessary to shut off the mains in the most seriously flooded areas. Remarkably, only 3 cases of typhoid had developed. Miss Sutherland expressed appreciation for the assistance rendered by the representatives of the DeLaval Pump Company and Wallace and Tiernan Company and that of J. B. Harrington, of the West Virginia Department of Health, who was drafted by the U. S. Public Health Service for emergency flood service at Paducah.

Consulting Engineers

J. S. Parker with J. S. Watkins, Lexington, Ky.; H. F. Wiedeman, Weideman & Singleton, Atlanta, Ga.; R. E. McDonnell, Burns and McDonnell, Kansas City, Mo.

W. M. LOVEJOY remarked that those who suffered damage to water utilities had something to console them when realizing such situations as that at Louisville where the electric utility had equipment valued at $18,000,000 under water. C. M. MCCORD, in reply to a question said that, contrary to reports in Chicago papers, the Memphis system was never in danger.

On Filter Plant Operation
(A Round Table—Led by Paul Weir)

With a few introductory remarks, Mr. Weir requested C. M. McCord, General Superintendent, Memphis Water Department, to give the members an account of Memphis experiences in iron removal by aeration and filtration.

MR. MCCORD, interestingly traced the history in the development of the Memphis supply from wells taking from a 500 ft. deep sand strata (once artesion flow) yielding a sterile water impregnated with iron, carbon dioxide and, at intervals, hydrogen sulphide. Employing air lift to the surface and centrifugal delivery to the treatment plant, the water was dropped 10 feet through 5 trays filled with coke to release gases, add oxygen. The precipitated iron (without benefit of added coagulant) largely settled out in sedimentation basins, was completely removed through rapid sand filters which were back-washed every third day regardless of the longer possible runs between washings. The coke in the aerating trays had been in service 12 years and was washed with a hose at intervals. No chemicals were added at any step and complaints from consumers were practically unknown. The supply constituted a 50/50 mixture of water of 10 parts hardness from one well field, and 50 parts from another, to yield a product of 25 to 30 parts hardness.

L. H. ENSLOW commented that he believed the Memphis water, taken from all angles, to be the most nearly ideal water of non-corrosive nature of any supply of size that he had knowledge of.

MR. MCCORD added that only one fact would cause him not to rate the water 100 per cent. He referred to so-called caustic embrittlement in boilers operating at 250 lbs. pressure, but not at lower pressure operation. Such had been corrected by sulphate additions to attain the SO_4/CO_3 ratio in the water in the boilers, as advocated by the American Society of Mechanical Engineers.

CARL ALEXANDER, Superintendent Water Works, Rome, Ga., in answer to a suggestion that caustic em-

Chlorinators and Cast Iron Pipers

1. Hal. Davis, Wallace & Tiernan Co.; 2. Ed. Murray, Mathieson Alkali Works; 3. Jeff. Corydon, Proportioneers, Inc.; 4. Tom Starnes, American Cast Iron Pipe Co.; 5. Paul Ivy, National Cast Iron Pipe Co.; 6. Ben. Crabbe, McWane Cast Iron Pipe Co.; 7. Leonard Saine, Walworth Co.; 8. Fred Dimmick, R. D. Wood & Co.

brittlement could happen only in case silicates were present, reported that silicate of soda was regularly added at his plant for control of corrosion. No embrittlement had resulted and tubes were now more easily cleaned than previously. An egg shell coating was formed in the mains.

W. J. ELDRIDGE, Supervisor of Water Supply, Du Pont Company, Old Hickory, Tenn., reported that boilers operating at 550 lbs. pressure had been kept practically scale and pitting free with a ferrous oxide compound (Allis-Chalmers' "Akon") added to the make-up water.

"Bleaching Clay in Coagulation," was the next topic of discussion. In this, MR. WEIR reported experiences at the Atlanta plant wherein activated carbon application had been moved to the water entering the filters, and bleaching clay added along with the coagulant. Thus using 17 lbs. per million dosage there had been a marked improvement—20 p.p.m. residual turbidity at the filters reduced to 5 or 6 parts with somewhat less coagulant. Result—filter capacities increased 33 per cent and carbon requirements materially lessened.

Mr. Weir said also that the 0.5 parts chlorine residual in the applied water from the chlor-amination of the raw water had been greater as a result and passed practically undiminished through filters. The combination of bleaching clay with pre-chlorination and carbon applied at the filters seemed to most effective and economical combination yet tried at Atlanta.

W. A. WELCH of Industrial Chemical Sales Div., W. Va. Pulp & Paper Co., in response to Mr. Weir's invitation, presented a brief explanation of the difference between just any charcoal and the scientifically activated charcoals as represented by "Nuchar." Mr. Welch explained in a graphical manner why powdered carbon did most effective work if applied in split dosage between the raw-water and the applied. He considered the clays better adsorbers of pseudo-soluble substances and oils in emulsion; whereas, carbons were more efficient adsorbers of soluble substances. On this basis it was appreciated that under some circumstances a combination treatment might surpass the use of either material singly.

H. G. TURNER, of the Anthracite Institute, was then invited to tell of the especial features of "Anthrafilt" in filtration and taste removal. In reply to questions, he had found that much depended on the proper preparation of crushed anthracite for its greatest effectiveness, and "Anthrafilt" was therefore "tailor-made," for the job at hand. Further, not less than 30 inch bed depth was recommended.

WM. H. LOVEJOY, Superintendent of Filtration, Louisville, Ky., had unsatisfactory experience with a trial filter containing Anthracite on top of sand and another of all anthractie. The difficulty consisted of humping up of mixed sand and coal in summer—less noticable in winter. Mud had not washed free with 15 to 18 in. wash rise, beyond which "anthrafilt" was wasted over wash troughs.

Mr. Turner, urged that the Louisville filters be washed as strongly as possible (26 inch rise) and the fine anthrafilt lost might look bad but would not be great. He agreed to replace all loss thereby—which he felt safe in saying would be insufficient to cause any material expense of replenishment.

On Pumps and Pumping

(A Round Table—Led by J. J. Dargan of Birmingham)

In the Round Table on "Pumps and Pumping" the following facts were developed:

Heating of ball-bearings had been traced to overgreasing—a clean out and a small amount of vaseline being the solution of this difficulty. Elbows or long radius bends connecting intake line to centrifugal pump suction caused unbalanced impeller conditions due to the centrepital side force of the intake water. Elbows or bends connected in vertical position to suctions had no undesirable effects. The dangers of packing becoming hard and cutting shaft sleeve justified a scheduled program of packing inspection and replacement more frequently than commonly practiced. A graphite-asbestos braided packing (Garlock No. 61 or equal) was considered best. Metallic packings (such as "Elco") should be used only on slow-speed pumps and was especially suitable for pumps handling gritty waters or sewages, where clean flushing water for bearings was not available.

Cavitation, indicated by a noise in the pump like pebbles being whirled through, was caused by air release from the water on the vacuum side of the pump, or when air was sucked in due to deficient submergence of intake pipe or through leaking suction line or bearings. The trouble was more pronounced as the negative suction head increased and the lower the temperature and greater the dissolved air content of the water. Such released air had been found to cut impellers badly. To kill swirl pool formation around vertical suction pipes, and air intake thereby, a floating circular

Chemists

C. V. Swearingen, City Water Co., Chattanooga; W. L. Lamar, U. S. Geol. Survey, Atlanta; Lewis Simonton, Supt. Filtration, Griffin, Ga.

raft with center hole through which the pipe passed, had been effectually used to dissipate the swirl created during low submergence of the foot valve.

In throttling oversized pumps it cost no less per hour for pump operation. No power was saved on the reduced flow because of the increased head due to throttling. Therefore the cost per m.g. pumped increased in proportion to the degree of throttling and reduction in water delivery. Where one pump was to be used for pumping against low or high head it was feasible to have duplicate units cross piped, to be operated in series for the higher heads, and singly or in parallel for the lower heads. Thus, low head booster or raw-water pumps could serve as high head or fire pressure pumps if desired. To reduce pump capacity one member stated that he had successfully cut 7/8 of an inch from a 22 7/8 inch diameter impeller, by turning it down and trimming the outer ends of the vanes. The pump had been noisy but gave no operating difficulties—350 H.P. being reduced to 280.

1. M. H. Collins, Rensselaer Valve Co.; 2. J. R. Brown, National Water Main Cleaning Co.; 3. Bill Ford, Mueller Co.; 4. E. L. Shuff, Builders Iron Foundry; 5. Howard Stilwell, Leadite Co.; 6. Ernest Vogt, Vogt Manufacturing Co.; 7. Bill Lyman, National Cast Iron Pipe; 8. T. F. Keenan, Pardee Engr. Co.

To prevent deep-well turbine type pumps from drawing down the water level below the intake, a 3/4 inch hole drilled through the lift pipe just below the lowest bowl of the pump was recommended by Mr. Dargan as a satisfactory preventative.

Contributing to the above discussion, beside Mr. Dargan, were Clark Cramer, Superintendent Pumping and Filtration, Lexington, Ky.; B. E. Payne, Superintendent Pumping Station, Louisville, Ky.; T. W. Coleman, Chief Engineer, Chattanooga Water Company, Chattanooga, Tenn.

Pipe Coating, Lining and Joint Materials

(Leader—Thomas F. Wolfe, Cast Iron Pipe Research Assn.)

In introducing this topic Mr. Wolfe dealt with the basic elements of design and structure of iron pipes; discussing, working pressure tolerances and resistance to water hammer; effects of and resistance to external pressures, such as earth loadings and stresses and traffic impact. He then covered the matter of pipe laying conditions and precautions to consider, the merits of flat bottom trench, the question of supporting blocks and shaped trench for minimum stress insurance.

W. W. BRUSH (New York City), commenting on breaks, assumedly due to traffic (truck) vibrations or impact loadings, said that his experiences had not shown that New York City breaks could be charged to street traffic impact. Requesting experience of others present, there was no evidence that traffic impact had caused a fracture of C. I. pipe beneath streets.

In discussing corrosion and tuberculation, Mr. Wolfe hastily reviewed developments which had led to greater attention to soil surveys and thicker exterior protective coating than the single tar dip in so-called "hot-spots." However, the wall thickness of C. I. pipe was primary consideration in precluding weakening from soil attack and mild electrolysis. Tuberculation and loss of carrying capacity had been sufficiently noticeable in the soft water areas to justify linings with cement mortar or bituminous enamels in extensions. And, for mains and service lines already laid, cleaning of mains followed by corrective treatment of the water to raise its alkalinity (pH value) and suppress attack.

On the subject of jointing, Mr. Wolfe pointed to the proven dependability of poured joints with lead or the less expensive compounds that had proved acceptable, if not preferable in the experience of many. As to mechanical joints, these had their place in special cases but, otherwise, their use on bell and spigot water pipes had been limited. As to pipes supplied with pre-run (ready prepared) lead for connecting and caulking, he had discovered many divergent views and asked for experiences and opinions of those present. The majority opinion expressed was not favorable to the use of prepared joints on the whole. E. O. SWEET (Birmingham) had sufficient experience, however, to cause him to consider the prepared joint an advantage. W. W. HURLBUT reviewed Los Angeles' experiences in jointing and wholly satisfactory results had been had with cement jointing properly done. Such joints had withstood earthquakes; this, possibly to the surprise of many. In joint preparation, the tar coating was burned off and the almost dry cement (17 lbs. water to 83 cement) was heavily and thoroughly caulked into place. On beaded end pipes no yarn was required in the cement jointing. Replying to A. F. Porzelius' question, Mr. Hurlbut said that expansion and contraction had not been a problem in Los Angeles; however, three breaks had been charged to contraction.

A. C. DECKER (Birmingham) commented on the very satisfactory behavior of the coal tar base lining on the new Birmingham Industrial Supply pipes. In the hot sun there had been no sagging, in winter no crazing or cracking.

E. O. SWEET, Sup't Birmingham Water Works, commented on his experiences with cement linings in C. I. pipes. A badly checked and loose lining had actually "healed" while in service, and the checking disappeared. C. I. pipes above 12 inch size were now being cut with an electric torch. The torch operator could cut a 36 in. pipe at a speed of 1 in, per minute. At cost of $3.00 per hour, a break in a 36 in. main had been repaired, costing between $20.00 and $25.00 for the cutting job. The operation gave a relatively even cut and surprisingly had not cracked, or otherwise damaged, the cement lining.

With Apologies

The Round Table on "Meter Testing, Repair and Maintenance of Services"—led by R. C. Warkman and O. B. Roberts of the Chattanooga Water Company—cannot be reported. An attempt was made to listen in, or secure reports, on as many of the four separate Round Tables as possible. This one had to be missed in the shuffle.

CONTROL OF THE ACTIVATED SLUDGE PROCESS *

The Why of Tapered Aeration

By MILTON SPIEGEL, STANLEY E. KAPPE and GILBERT M. SMITH

Sanitary Engineers,
Chicago Pump Company,
Chicago, Ill.

THIS discussion presents a general review of the accomplishments of certain investigators in the development of a rational basis for controlling the activated sludge process.

The object of this paper is three-fold: One, to present to the operating engineer measures for controlling the activated sludge process under varying conditions of sewage flow and strength. Two, to present to the designing engineer a basis for the design of activated sludge batteries to afford efficient operation control and power economies. Three, to present to the investigator a theory of oxygen utilization by activated sludges as a basis for further research.

History

Nordell, in 1916, while working on the basis of design for the proposed activated sludge plant for Milwaukee, performed numerous experiments on the oxygen utilization characteristics of activated sludges. This investigation was undertaken because aeration represented the greatest single cost of plant operation and appeared to be one of the factors for controlling the activated sludge process.

In 1934, Kessler, professor of Hydraulic and Sanitary Engineering at the University of Wisconsin, instituted a research program to check Nordell's discoveries at Milwaukee. This work was performed at the Monroe, Wisconsin, sewage treatment plant, under the auspices of the University of Wisconsin Engineering Experiment station and with the advice of Nordell.

The Monroe plant is of the activated sludge type employing mechanical aeration. Sewage coming into this plant has abnormal strengths, varying from 500 to 1,000 p.p.m., in the 5-day B.O.D., due to cheese wastes mixed with domestic sewage. The flow varies from 300,000 to 600,000 gallons per day.

At the time this research was instituted, the Monroe plant was not producing a well-activated sludge. The activated sludge used in the oxygen utilization experiments was built up and maintained in a separate tank with a mechanical aerator made available by the Chicago Pump Company.

After the research program at the Monroe plant was finished, Kessler conducted extensive tests at numerous activated sludge plants throughout the country to check the results obtained at Monroe. The data and conclusions obtained from the research at Monroe and the tests conducted at various other plants were reported in an article on "Oxygen Utilization by Activated Sludge" written by Kessler and Nichols, published in the Sewage Works Journal, September, 1935.

One of the by-products of the research program conducted at the Monroe plant was the re-habilitation of the aeration battery, to afford the consistent production of a well activated sludge. This work and the results obtained therefrom was described in an article by Kessler, Rohlich and Smart, on the "Tapered Aeration of Activated Sludges," published in Municipal Sanitation, August, 1936.

Sludge Activity and Oxygen Utilization

It is of importance to establish the definitions of the terms, "sludge activity" and "oxygen utilization" in the light of their application to the findings of the foregoing investigations.

Sludge Activity: "Sludge activity" describes the biological activity present in activated sludges.

The presence of living organisms in the sludge, maintained under aerobic conditions, is necessary to accomplish purification by the activated sludge process. This is a point agreed upon by most investigators. Because of these characteristics, Ardern and Lockett suggested that the sludge be called "activated sludge."

Terms for the expression of the concentration of solids in activated sludge—sewage mixtures such as, weight of dry solids, are not indicative of the sludge activity. Studies of many sludges have shown that only a portion of the total solids in activated sludge-sewage mixtures were activated. Mohlman discovered that with well-activated sludges, the activity was proportional to the volatile matter present.

The sludge activity in activated sludge-sewage mixtures is subject to variation and only can be kept more or less constant by external control, *i. e.,* retention or wastage of sludge.

Oxygen Utilization: The term "oxygen utilization" applies to the oxygen utilized by the biological activity present in an activated sludge.

Kessler, in deference to the work done by Nordell named the rate of oxygen utilization by activated sludge, the "Nordell Number." The unit of measurement of this term is parts per million of oxygen utilized per hour.

"Sludge Activity," and therefore "purification power," of an activated sludge is measured by its rate of oxygen utilization.

A quantitative increase in the concentration of sludge in the aeration battery increases the rate of oxygen utilization by the mixture. The latter increase indicates a greater sludge activity. However, the increase in sludge activity is not proportional to the total amount of sludge added, as a portion of this sludge contains unactivated solids. The increase in sludge activity is proportional to the amount of activated solids added, and is measured by the rate of oxygen utilization of the mixture.

Measurement of Oxygen Utilization

Nordell originally employed what was virtually a very short period B.O.D. determination to measure the rate of oxygen utilized by activated sludges.

The measurement of the oxygen utilization rates determined at Monroe were sharpened by an improvement in method suggested by Palmer and Beck of the Chi-

*This paper, prepared for publication in WATER WORKS AND SEWERAGE, was presented before the New York State Sewage Works Association, at its 1937 annual meeting in New York City. —Ed.

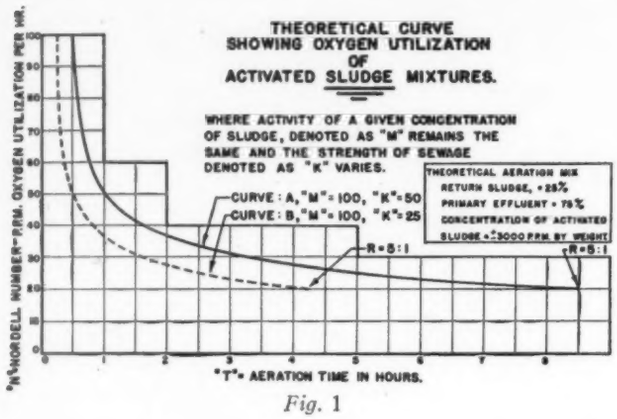

THEORETICAL CURVE
SHOWING OXYGEN UTILIZATION
OF
ACTIVATED SLUDGE MIXTURES.
WHERE ACTIVITY OF A GIVEN CONCENTRATION OF SLUDGE, DENOTED AS "M" REMAINS THE SAME AND THE STRENGTH OF SEWAGE DENOTED AS "K" VARIES.
THEORETICAL AERATION MIX
RETURN SLUDGE, = 25%
PRIMARY EFFLUENT = 75%
CONCENTRATION OF ACTIVATED SLUDGE = 3000 P.P.M. BY WEIGHT
CURVE: A, "M" = 100, "K" = 50
CURVE: B, "M" = 100, "K" = 25
R = 5:1
R = 5:1
"N" NORDELL NUMBER - P.P.M. OXYGEN UTILIZATION PER HR.
"T" = AERATION TIME IN HOURS.

Fig. 1

cago Sanitary District. This modification consisted principally of the employment of a copper sulphate to inhibit oxygen utilization, by an activated sludge-sewage mixture, and to facilitate rapid settlement of the sludge.

Briefly, the measurement of the rate of oxygen utilization at Monroe comprised the following procedure: Two large-mouthed bottles were filled with the activated sludge-sewage mixture. One bottle was immediately inoculated with a copper sulphate solution to inhibit further oxygen utilization, and then was tightly stoppered. The other bottle was tightly stoppered and shaken, or agitated, for a short period, say ten minutes. After shaking, this bottle was also inoculated with a copper sulphate solution. When the floc in both bottles had settled for about ten minutes, dissolved oxygen determinations were made on the supernatant. The difference between the dissolved oxygen content of the two supernatants was the reduction for the period the second bottle was shaken. This reduction was converted to a Nordell Number, by computing the rate of oxygen utilization in parts per million per hour.

A detailed description of this method and the variations developed may be found in the article on "Oxygen Utilization by Activated Sludges." — Sewage Works Journal, Sept., 1935. The great amount of labor involved in this chemical method, and the potentiality for inaccuracy due to the personal equation, led Nordell to develop the "Odeeometer,"—a meter for determination of O. D., or oxygen demand.

The Odeeometer measures the shrinkage of the air, in a closed chamber, due to the oxygen utilized therefrom by an activated sludge-sewage mixture contained within this chamber. A small, partially submerged, paddle-wheel constantly stirs the mixture. The rate of movement of a globule of oil in a, calibrated, capillary tube, connected to the closed chamber, determines the rate of oxygen utilization by the mixture. A complete description of the construction, operation and application of the Odeeometer has been presented in an article by Kessler, "The Odeeometer—Its Place in the Control of Activated Sludge Plants," published in WATER WORKS AND SEWERAGE, January, 1936.

Oxygen Utilization by Activated Sludge-Sewage Mixtures

The well defined results obtained at the Monroe plant showed that the rate of oxygen utilization by activated sludges followed a definite law. Curves, plotted from the data obtained, showed that the rate of oxygen utilization was at a maximum for a short period after the raw sewage and activated sludge were initially mixed. Following this maximum, the rate of oxygen utilization fell off sharply and then decreased more slowly, until the curve had a very slight slope.

Nordell, after considerable study of the Monroe curves, derived equations for the mathematical expression of the general law of oxygen utilization by activated sludge-sewage mixtures. Following this, Kessler studied the rates of oxygen utilization at numerous activated sludge plants throughout the country. His findings substantiated the conclusions reached in the Monroe experiments. Plants where Kessler conducted these studies were at Williams Bay, Milwaukee, and the Madison experimental aerator in Wisconsin; Flora, Illinois; Newark, N. Y., and Morristown, Madison-Chatham and Bernardsville, in New Jersey.

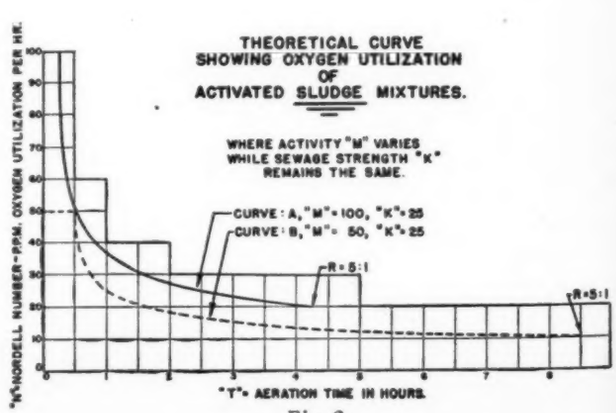
The Curves:

Curves 1 and 2 illustrate this law and the variation of the principal factors involved. The ordinate shows the rate of oxygen utilization of an activated sludge-sewage mixture in p.p.m. per hour. The abscissa shows time measured in hours, with zero as the point where raw sewage and activated sludge are initially mixed. On curve [A] the horizontal line shows the maximum rate of oxygen utilization which persists for a time proportional to the sewage strength. The curve drops off sharply and then more slowly.

Numerous experiments demonstrated that the sludge possessed good flocculation characteristics when the flat portion of the curve was reached. With sewage having B.O.D.'s upward of 150 p.p.m. the point on the curve where a good sludge index was obtained was approximately represented by a rate of oxygen utilization of ¼ to ⅕ of the maximum rate. Where sewage strengths were from 50 p.p.m. to approximately 150 p.p.m. B.O.D., this ratio was from ⅓ to ¼.

Following curve [A], the sludge activity is denoted by "N" at any time, "T." And "N" is the Nordell Number, rate of oxygen utilization in p.p.m. per hour. "T" is aeration time in hours, measured from zero as the time when the activated sludge and sewage are initially mixed. The maximum activity of the sludge is denoted by "M." Since "M" is the maximum "N" it is likewise expressed in p.p.m. per hour of oxygen utilization. "M" on curve [A] is 100. "K" has been chosen as an index of sewage strength and is equal to the product of M and the time Tm in hours over which M persists. Therefore, "K" equals M x Tm.

In numerous plants over the country it has been found that "K" roughly approximates 1/10 of the 5-day B.O.D. of the sewage coming into the aeration tank. The horizontal line, showing the maximum rate of oxygen utilization, is sometimes masked by abnormal conditions. One, the excess oxygen demanded by substances normally foreign to fresh domestic sewage. Two, the inhibiting effect of certain substances which may


THEORETICAL CURVE
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WHERE ACTIVITY "M" VARIES WHILE SEWAGE STRENGTH "K" REMAINS THE SAME.
CURVE: A, "M" = 100, "K" = 25
CURVE: B, "M" = 50, "K" = 25
R = 5:1
R = 5:1
"N" NORDELL NUMBER - P.P.M. OXYGEN UTILIZATION PER HR.
"T" = AERATION TIME IN HOURS.

Fig. 2

be present in the sewage. Three, the technique of the person conducting the oxygen utilization determination.

Curve [A] shows a maximum sludge activity, "M," of 100 which persists over ½ hour to give a "K" value of 50. A ratio, "R," of 5 to 1 is reached in 8½ hours. This time "T" represents the aeration period necessary to produce a well conditioned sludge. Curve [B] shows what would theoretically happen if the sewage strength represented by "K" was halved. "M" is still 100 and persists over ¼ hour to give a "K" value of 25. The point where the ratio, "R," is 5 to 1 on curve [B] is reached in 4¼ hours, and represents the aeration time required by a sewage of ½ the strength, "K." *This phenomenon is the basis of a general law—that, in any given activated sludge-sewage mixture with a constant maximum sludge activity the time of aeration required is directly proportional to the sewage strength.*

Curve 2: Curves A and B illustrate what happens when the sewage strength remains constant and the maximum sludge activity varies. Curve [A] represents an activated sludge-sewage mixture with a maximum activity of 100, persisting over ¼ hour, giving a "K" of 25. The ratio 5 to 1 is reached in 4¼ hours. Curve [B] represents an activated sludge mixture with a maximum sludge activity of 50, persisting over ½ hour, giving a "K" of 25. The ratio of 5 to 1 is reached in an aeration period of 8½ hours or twice the aeration period required in Curve [A]. *The general law illustrated here is, that in any given activated sludge-sewage mixture where the sewage strength remains the same, the aeration period required to produce a well conditioned sludge varies inversely with the maximum sludge activity, "M."*

Comparison of Oxygen Utilization and B.O.D. Reduction

Quoting from Prof. Kessler's article on the Odeeometer in WATER WORKS & SEWERAGE, January, 1936 . . . "Figure 4, for August 23, 1934, shows results of oxygen demand tests obtained on sewages of different strength in separate tanks, being treated by activated sludges that were not identical in quantity or activity.

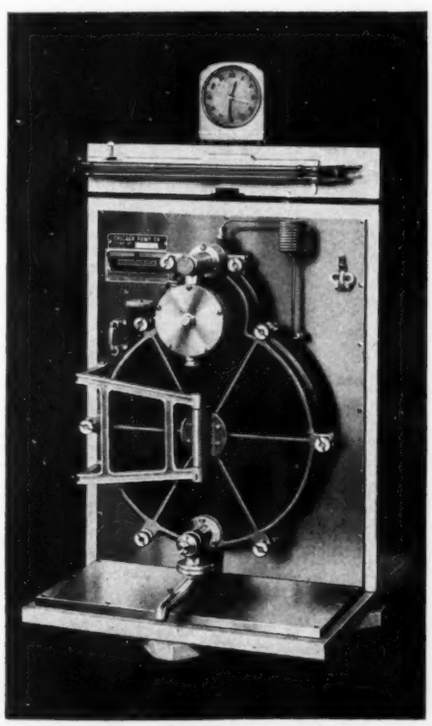

Fig. 3—The Odeeometer—Employed to Determine Rate of Oxygen Utilization by Sludge-Sewage Mixtures.

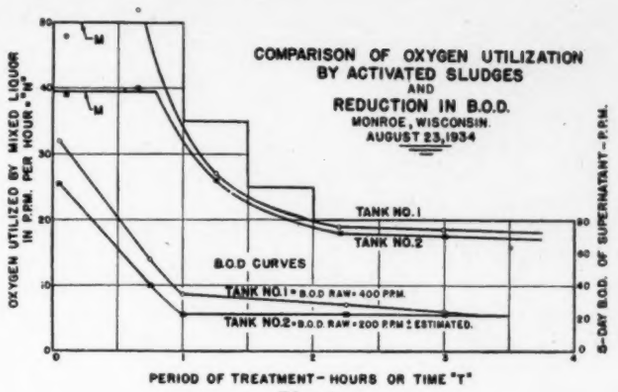
COMPARISON OF OXYGEN UTILIZATION
BY ACTIVATED SLUDGES
AND
REDUCTION IN B.O.D.
MONROE, WISCONSIN.
AUGUST 23, 1934
TANK NO. 1
TANK NO. 2
B.O.D CURVES
TANK NO. 1 - B.O.D. RAW - 400 P.P.M.
TANK NO. 2 - B.O.D. RAW - 200 P.P.M. ESTIMATED.
OXYGEN UTILIZED BY MIXED LIQUOR IN P.P.M. PER HOUR - "M"
5-DAY B.O.D. OF SUPERNATANT - P.P.M.
PERIOD OF TREATMENT - HOURS OR TIME "T"

Fig. 4.

As the tests for rate of oxygen absorption proceeded, samples were taken of the mixed liquor and B.O.D. determinations were made, but of course were not available until August 28th." . . .

"Figure 4 indicates that as long as the maximum rate of absorption 'M' remains constant, the B.O.D. of the supernatant of the mixed liquor is decreasing at an exceedingly fast rate and as soon as the rate of oxygen absorption decreases, the decrease in the B.O.D. of the treated liquor takes place very slowly. If Ridenour's curves (Sewage Works Journal, Vol. 7, No. 1, Jan., 1935) are plotted to the same ordinate they would be almost identical to these curves, except that for his curves the period of rapid B.O.D. reduction lasts only about five minutes, whereas the period of the August 23rd test was about 60 minutes. This difference in time can be explained partially by comparing the strength of the raw sewage. Ridenour working with 185 B.O.D. as against 400 B.O.D. in the above test."

Application to Plant Control

Studies of the application of these laws to actual plant operation have been conducted at the Monroe, Wis., and the Flora, Ill., activated sludge plants during the past two years. Both these plants receive sewages of abnormal strength. The Monroe sewage comprises domestic and cheese plant wastes. The Flora sewage is a stale, highly concentrated domestic waste, due to low per capita water consumption and flat grades in the sewer system. Sewage flow characteristics at the Monroe plant show high daily surges in rate, while the Flora flows are subject to extreme variations between the summer season and the balance of the year.

The conclusions drawn from these studies of actual plant operation show that the application of the previously discussed laws afford simple and effective control of the activated sludge process to the end that high degrees of purification may be constantly produced under widely varying conditions of sewage flow and strength with a material economy in power requirements.

The controllable factors in the process are sludge activity and oxygen supply. These factors are measurable. Sludge activity is indicated by the Nordell Number, the rate of oxygen utilization expressed in p.p.m. per hour, and is simply measured by the Odeeometer. The rate of supply of oxygen required during various critical portions of the aeration period is a factor of the activity of the sludge, the strength of the sewage and the available aeration period. Quantitatively, the oxygen required is determinable by oxygenation curves produced by Odeeometer tests. The sufficiency of oxygen supply throughout the aeration battery can be readily checked by the dissolved oxygen test on catch samples of the mixed liquor at various points.

The general procedure for control of the activated sludge process comprises the maintenance of a sludge activity, "M," which under the selected operating condition of sewage strength and flow, will produce a well-activated sludge within the aeration period available. "M" is the maximum rate of oxygen utilization by the sewage-sludge mixture, and is indicative of the maximum activity of the sludge.

The desired maximum sludge activity may be maintained by controlling the wastage and retention of the sludge produced in the aeration battery. The sludge index, as derived by Donaldson, Theriault, and Mohlman, the ratio of volume to weight, or vice versa, can be employed to determine the optimum ratio of "R"—the ratio of the maximum oxygen utilization rate to the final rate necessary to obtain a well-activated sludge. The settling characteristics of the sludge can be readily determined by the simple settling test.

Tapered Aeration

As indicated by the oxygen utilization curve for the operating conditions selected, the oxygen supply can be tapered off from the initial portion of the aeration period where the sludge activity is at a maximum, to the end of the aeration period where the rate of oxygen utilization is but a fraction of the initial rate.

Regulation of oxygen supply to obtain purification control, power economy, or both in existing mechanical aeration or air diffusion plants, where present equipment does not lend itself to the desired flexibility, can be simply instituted by the addition of recently developed aeration apparatus in the initial portion of the aeration battery. For proposed activated sludge plants, aeration apparatus having flexible oxygenation capacity characteristics can be employed to advantage to obtain the purification-control and power economy afforded by the application of the foregoing principles.

Certain preliminary studies would have to be undertaken before existing activated sludge plants could be placed under control. For instance, in a plant where there is a great variation between dry and wet weather sewage flow and strength, one basis of regulation would prevail for dry weather, and another for wet weather conditions. The operator could, either by estimate, based on past experience, or by actual investigation, determine the operating sewage flow and strength for these seasons. Then, with the Odeeometer a number of oxygen utilization curves could be determined for various days during each season. His past knowledge of sewage strength and flow variations could be correlated with the characteristics of the oxygen utilization curve. This study would give the operator sufficient data to set optimum operation conditions for the period of regulation chosen. Daily control would comprise the maintenance of the desired maximum sludge activity and a sufficient oxygen supply to support this activity.

The degree in which the activated sludge process is controlled with respect to varying sewage flows and strengths is dependent upon the size of the plant and the economies which may be afforded by close regulation. In many plants the power savings available by tapering off the air supply proportional to the oxygen utilization curve would result in sufficient economies to justify comprehensive field studies for plant regulation.

In the operation of small activated sludge plants longer periods of regulation and higher factors of safety are indicated to maintain control of purification without too close supervision. The collection of sewage strength and flow data, say, during the first year of regulation would afford a basis for inducing further economies by lowering the factor of safety consistent with the operation supervision available.

The main advantage in controlling an activated sludge plant in accordance with the laws set forth in this discussion is purification control. A secondary advantage which has not been stressed in this discussion is the power economy which can be effected by regulating the air supply in accordance with the oxygen utilization curve and the minimum tank velocities necessary to maintain suspension of the solids.

Studies of a large air-diffusion plant, of approximately 200,000,000 gallons per day capacity, led to theoretical estimates which indicated that a power saving of 25 per cent [$20,000 annually] could be instituted by the inclusion of a newly developed air diffusion system operating on the tapered aeration principle.

Conclusion

The numerous experiments and tests performed at the Monroe Sewage Treatment plant and checked at various activated sludge plants throughout the country indicate the following conclusions regarding the activated sludge process:

1. Sludge activity is the controlling factor in the activated sludge process.
2. The rate of oxygen utilization of activated sludge-sewage mixtures is a measure of sludge activity.
3. The rate of oxygen utilization of an activated sludge-sewage mixture is readily measured by the Odeeometer.
4. When activated sludge and raw sewage are initially mixed, the rate of oxygen utilization is at a maximum, persisting uniformly for a time proportional to the strength of the sewage. The rate of oxygen utilization then drops sharply and subsequently more slowly until a point is reached where good purification and a well-activated sludge is obtained.
5. The aeration period required to produce a well-activated sludge is inversely proportional to the maximum activity of the sludge and is directly proportional to the strength of the incoming sewage.
6. An activated sludge plant may be controlled on a rational basis by maintaining a maximum sludge activity consistent with the operating sewage strength, so that the sludge is in a well-activated condition throughout the aeration period.

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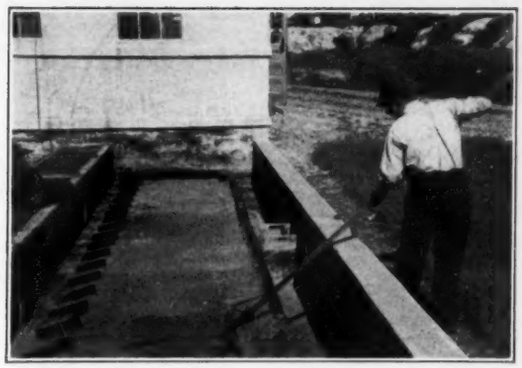
New Pipe Manual

The well known American Pipe Manual, in its 10th Edition, has just been announced by The American Cast Iron Pipe Company as now being ready for free distribution.

The new edition of 205 pages is put together with the modern "plastic" binding, which allows the open book to lie flat. It contains much new material and several of the newer ACIPCO products are therein listed for the first time, with ample illustrations of the products and step by step action photographs of the adaptations and assembly of various mechanical joints. For many years a useful source of technical information for those who design, specify or purchase pipe and pipe line appurtenances, the new 10th edition is more replete than ever in tables and reference information for engineers, and superintendents. For a copy of the 1937 American Pipe Manual gratis, address any branch office of the company, or the headquarters offices of The American Cast Iron Pipe Co., Birmingham, Ala.

CHLORINATED AIR PROVES AN AID IN GREASE REMOVAL



Skimming the Traps During Chlorination. More Work for the Operators; But Less Grief in the Plant Beyond.

By HARRY A. FABER*

Research Chemist
The Chlorine Institute, Inc.
New York, N. Y.

ONLY limited study has so far been given to the problem of removing grease from sewage. In a separate sewer system the content may be low, but in a combined sewer system industrial wastes may excessively increase the grease content. In activated sludge type of treatment plants such substances as oil and grease interfere with efficient aeration and sewage purification. To a lesser degree, grease and oil interfere with other sewage treatment operations and result in lower sedimentation efficiencies.

In several activated sludge plants provision has been made to partially remove oil, grease, soaps, and floating debris ahead of the aeration process. Attempts have been made to increase the amount of this material collected by means of a short period of diffused air aeration. Partial coalescence and flotation of such substances, and removal thereafter as scum, appears to be caused by the air blowing process. Not all grease rises to the surface by such treatment but, because it remains in an emulsified form or exists as a coating on heavier particles, is carried with the sewage flow. This aeration—skimming process is only partially effective in grease removal and little data is available as to the most efficient tank design or air application.

Wool Grease Recovery Methods

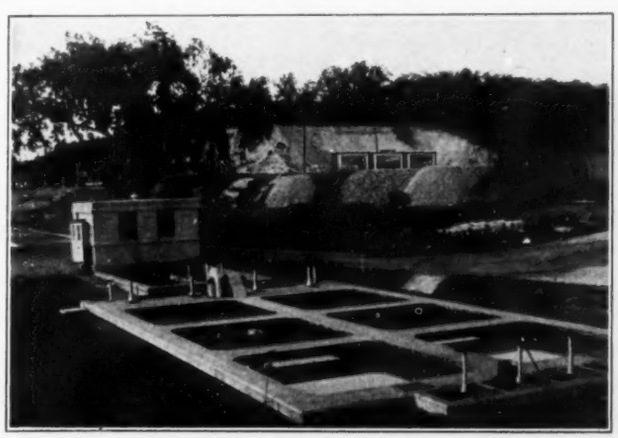
It appears that the only attempts to study improvements in grease yield from industrial wastes have been in connection with wool washing effluents. Raw wool contains a high percentage of grease which is removed by washing in warm water with alkali or soap. The waste grease is mixed with suspended mineral and organic matter and does not readily separate out. Acid "cracking" of the washing water to recover wool grease (lanolin) is practiced in a few instances. By reacting on the alkali content the acid treatment releases some of the grease, but it does not destroy the protective colloid effect of the protein material.

A more logical method of wool grease recovery is reported (1) as used by J. de Raeve in Australia. Oxidation of proteins by chlorination apparently has no effect on the fats. It does destroy the protective colloid effect of the proteins which appears to be more largely responsible than is the alkali in preventing the liberation of grease. Chlorination of wool washing effluent to form hypochlorous acid was practiced to free the grease which was then recovered by flotation and skimming. While this work was done on wool washing waste, it appeared that a similar effect might be expected to occur with sewage grease. In consequence of indications noted at several plants employing pre-chlorination of sewage and, in particular some observations during chlorination experimentation at the Baltimore Treatment Works, it was decided to undertake an experiment wholly confined to grease removal.

Plant Scale Experiment

For two reasons, the activated sludge plant at Woonsocket, R. I., appeared a desirable site for the experiment. First, the physical equipment of this plant is suitable. A grease skimming tank using aeration is in regular operation ahead of the primary settling tanks. Second, the Woonsocket sewage has a high grease content because it receives wastes from such industries as wool scouring, rayon manufacture, and weaving processes.

Aeration during a six minute detention period (at normal flows) is provided. No facilities are available

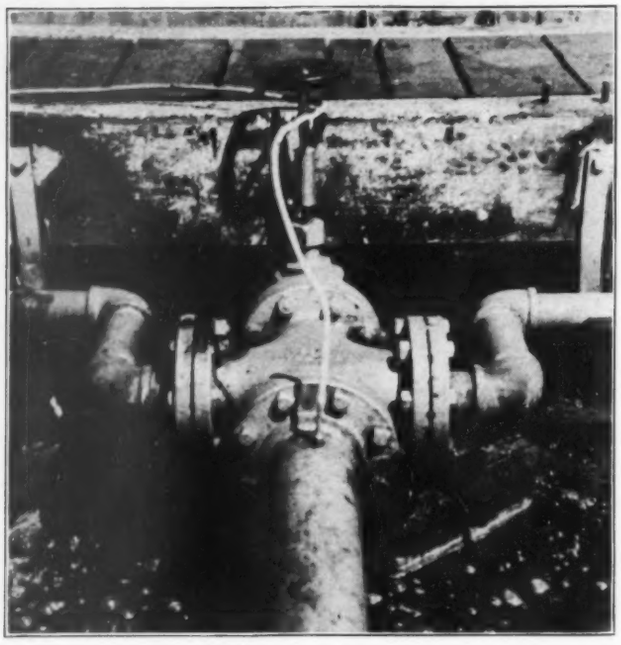


Primary Units, Woonsocket Plant, Between the Settling Tanks and Screen House Appear the Aeration Tanks for Grease Separation, Trapping and Removal by Hand Skimming.

REFERENCES

[1]Clarification of Wool Scourers' Effluent and Recovery of Wool Fats. Jean de Raeve. Industrial and Engineering Chemistry, Vol. 17, No. 8, p. 837 (Aug., 1925).

*Associate Editor, WATER WORKS AND SEWERAGE.



Chlorine Gas Feed-Tube Connected Into Air Header of Grease Separation Tanks.

for metering the air supply to this tank, but experience has made it possible to employ a rate which accomplishes greatest flotation of grease. The study was confined to a comparison of aeration at the usual rate, with and without the addition of chlorine.

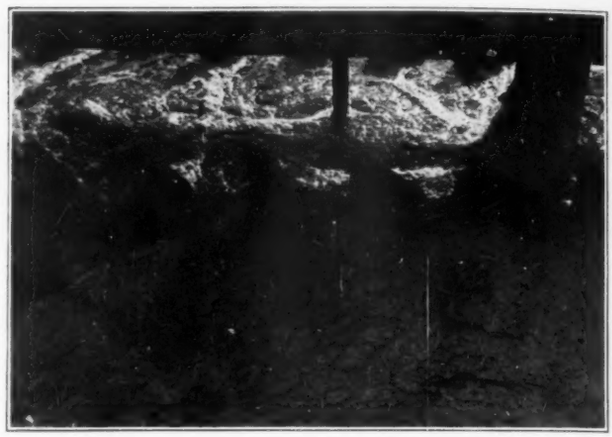
To secure the maximum effect of chlorination it seemed desirable to add chlorine as near the point of air-diffusion as possible. For this reason it was decided to confine the study to the introduction of gaseous chlorine directly into the compressed air line. Previous experience had indicated the value of efficient flash type distribution of the chlorine which would be accomplished in this scheme. Other experiences had indicated that the only point on the air-diffusion system at which minor chlorine injections might prove damaging was to the drop pipes immediately above the submerged air-diffusers.

Low Chlorine Dosages Necessary

The original plan was to study the relation between chlorine dosage and grease removal results. A limiting factor at Woonsocket soon became apparent, however, in that the porous tube air diffusers are located at a depth of only three feet below the surface of the skimming tank. Because of the shallow depth, air bubbles rise to the surface with only a relatively short travel and consequently brief air-sewage contact period. Thus the chlorine content of the air could not be large or, else, unabsorbed gas would be released at the surface and chlorine would be wasted to the atmosphere. Chlorination was, therefore, adjusted to feed at slightly below the point at which a chlorine odor became perceptible at the surface of the sewage.

Aeration Units at Woonsocket. With His Back to the Primary Units, the Reader Is Looking Toward the Digesters and Sludge Beds Beyond.

From Table 1 it will be noted that the average chlorine dose was under 1.5 p.p.m., when calculated on sewage flow. Tests for chlorine in the treated sewage at no time showed the presence of any residual. There is some evidence that a somewhat increased dose would have resulted in greater effectiveness in freeing grease, and the physical conditions of depth and adsorption permitted.



Close-Up of the Grease Froth Accumulating Within the Baffled "Trap." Lifted by Blowing With Chlorinated Air in the Center Compartment, Wave Action Pockets It in the Traps on Either Side.

TABLE 1—GREASE RECOVERY EFFICIENCY USING CHLORINATED AIR

	Pounds Wet Grease per m. g. Sewage		—Additional Yield—		P. P. M.*
	Usual Aeration	Chlorinated Aeration	Yield Pounds per m. g.	Per Cent Increase	Chlorine Applied
Sunday	1.3	5.3	4.0	408	1.51
Monday	14.0	29.0	15.0	207	1.47
Tuesday	12.2	23.0	10.8	189	1.47
Wednesday	3.6	10.0	6.4	278	1.41
Thursday	3.9	10.3	6.4	264	1.68
Friday	3.9	10.0	6.1	256	1.40
Saturday	2.4	10.6	8.2	442	1.38

*Calculated from total chlorine applied and total sewage flow each day.

Measurement of Released Grease

Determination of the grease content of the raw and aerated sewage by Standard Methods of Analysis proved difficult. Accurate composite sampling would be necessary and facilities for carrying out analysis were not available at the plant laboratory.

It appeared that the most dependable measure of efficiency (certainly the most practical) would be to remove and weigh the total grease collected in the form of scum on the tank. Because of the baffle arrangement of the tank, grease could be collected over an entire 24 hour period—(see picture). By using a screen skimming device for coarse scum and a cheesecloth skimmer for fine scum the daily accumulation could be determined. The skimmings were drained to allow easily separable water to run off and were weighed in light metal (tared) cans.

By weighing the relatively large 24 hour accumulation of grease, it is believed that reasonable accuracy of grease yield comparison was obtained. Since aeration

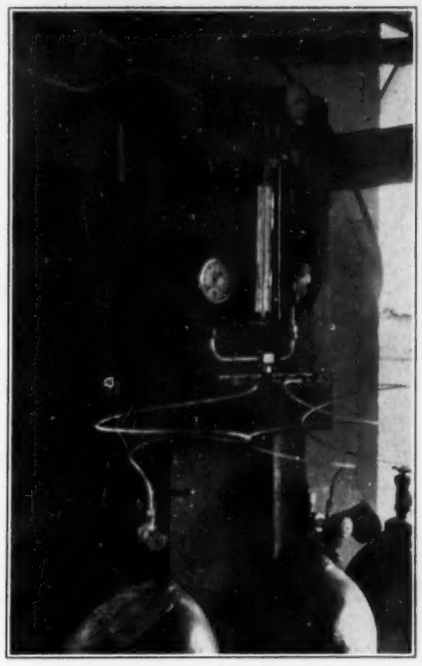
and all other conditions were maintained as constant as possible, it appears that differences in grease collection would indicate the effects from the addition of chlorine to the air. In this way, actual plant operating conditions were measured in a practical manner.

Results of Operation

Preliminary runs were made for a number of days, using only visual comparison of grease accumulating on the skimming tank, with and without the addition of chlorine to the air line. It was noted that, as would be expected, the grease yield on different days of the week showed wide variation. While it is recognized that a study confined to two weeks of operation may not be typical of yearly operation, at least the daily variation and an indication of chlorination effectiveness should be proven.

As finally carried out, the experiment consisted of aeration with chlorinated air for the week of October 22nd to 28th, 1936, and aeration in the usual manner for the week of October 29th to November 4th, 1936. At the end of each 24-hour period the total grease was collected and weighed. Daily sewage flow was recorded and varied between 3.0 m.g.d. and 3.8 m.g.d. During the two week period the flow for corresponding days showed no more than 0.2 m.g.d. variation. In order to facilitate a comparison of removal results, the grease recovered has been computed on a million gallon basis.

These results are given in Table 1. They indicate that a gaseous chlorine dose, averaging less than 1.5 p.p.m. (based on sewage treated), effected increases in grease removal ranging from 189 to 442 percent. While there is wide variation in the daily amount collected, it appears that from Monday through Friday the percent of increase in yield is surprisingly constant. Saturday and Sunday grease collections, while less in amount, show higher percentage yields, which vary from 408 to 442 per cent increase during chlorination. These results are compared in Table 2. On these days practically no industrial waste is received at the plant and the sewage is almost entirely domestic in nature, yet the percentage yield of grease was practically doubled. Figure 1 shows graphically the pounds of grease per million gallons of sewage as collected by the two methods. (Since the chlorine demand of the domestic sewage was naturally considerably less than that of the combined sewage, and the relative grease separation from the domestic sewage was considerably greater; it may be reasoned that, if practicable, a higher chlorine dosage would have yielded higher grease separations from the combined sewage.)



The Chlorinating Equipment. Obsolete But Serviceable and Compact Was This Old Style W&T "Dry Feed" Control Panel. Through Flexible Copper Tubing the Gas Was Taken to the Air Header.

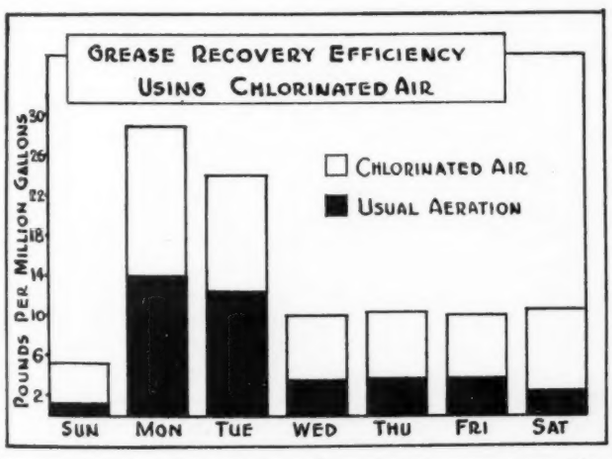


Fig. 1—Graphical Comparison of Grease Yields—With and Without Chlorinated Air.

TABLE 2—GREASE RECOVERY VARIATION WITH TRADE WASTE IN SEWAGE

Wet grease, lb./m.g.	Saturday and Sunday	Monday to Friday, Incl.
(a) By usual aeration	1.85	7.5
(b) Chlorinated aeration	7.95	16.5
Increase in yield	430%	220%
Chlorine dose applied (P.P.M.)	1.45	1.48

Discussion of Results

While it was possible, in the Woonsocket experiment, to apply only a small dose of chlorine to the diffuser system, in the aeration of sewage for grease removal, the result indicates that a definite increase in grease separation can be accomplished by this method with modest chlorine dosages. It was expected that the recovery of grease from this sewage, which contains a high grade content because of the industrial wastes present, would be more marked than from purely domestic sewage. The limited runs indicate, however, that the yield of grease from domestic sewage, when blown with chlorinated diffused air, may prove to be proportionally higher.

The effectiveness of this method of grease removal, as applied to a strictly domestic sewage, is to be studied by C. E. Keefer and staff in more detail during 1937, at the main treatment works of Baltimore, Md. The results of varying aeration time, chlorine dose, and other factors should indicate significant points in the process. And, if more complete removal of grease can be accomplished effectively and economically by this means, the load on primary units, aeration tanks, trickling filters or sand beds may be greatly reduced. In the case of primary treatment, alone, grease filters on shore lines and waterways may be eliminated along with bacterial pollutions.

Full acknowledgment should be made of the helpful guidance of Mr. L. H. Enslow, of the Chlorine Institute. Also, for the valuable assistance contributed in this experiment by Mr. E. K. Marrah, Superintendent of the Woonsocket plant, and by the plant operators who made weighings and took samples. The cooperation of the Rhode Island and New York Health Departments was of value in the work. Chlorine feed equipment was provided by Wallace and Tiernan Co., and the liquid chlorine by Fields Point Mfg. Company of Providence.

Montreal's MacTavish Pump Station; Overlooks McGill Univ.; Supplies the Intermediate and High Level Zones.

MONTREAL HOST TO A.W.W.A.'S CANADIANS

TO MONTREAL, its "organization cradle" of 1920, the 17-year old Canadian Section of the American Water Works Association returned April 14-16th for its 1937 meeting in this interesting cosmopolitan city of two languages and two peoples—French and British Canadians. In 1925, the year of the last meeting in Montreal, 167 was the registered attendance. This year, with only a few of the original 16 members on hand, the registration was 338, representing more than a 100 per cent gain over any other meeting of the Section held in Eastern Canada.

Believed to be financially the strongest A.W.W.A. Section and directed by a secretary, of whom there is no "whomer," and who the Canadians are sending to A.W.W.A.'s Board of Direction as its contribution, the Canadian Section has grown in membership and in service to its members. Outstanding has been the work of Secretary Berry's office in collecting, assembling and distributing to members and city authorities "Canadian Water Works Statistics," the value of which have been previously commented upon in this magazine, as a pattern for other sections in cooperation with the central offices of A.W.W.A.

On hand was Executive Secretary Harry E. Jordan, from A.W.W.A. headquarters to observe the prowess of the Canadians; to hear members first hand appraisal of the good work of their Secretary's office and the genuine value of the Water Works Statistics for the use of members and, moreover, in focusing attention of others on the association, and, too, to compliment the Canadians and Secretary Berry on having the most efficiently run section in A.W.W.A., which could well serve as a model for others. In fact, he expressed the wish that other section secretaries could be present to share with him the inspiration gained. It was men like Canada's Dobbin, who A.W.W.A. was privileged to make an Honorary Member; and, men like Canada's Berry who was being sent as a real asset to the National Board of Direction, that spelled success for A.W.W.A.

F. P. Adams, City Engr. and Water Works Mgr., Brantford, Ont. (Retiring Chairman)

E. V. Buchanan, Genl. Mgr., Public Utilities, London, Ont. (Incoming Chairman)

Opening Luncheon

Opening with a luncheon attended by 215, President F. P. Adams recited a brief review of the Section's history since its birth 17 years ago in Montreal and what had been accomplished in water supply progress in Canada since.

Montreal's Mayor Pro-Tem, Omer Code, delivered a welcome (first in his native French and then in English) the high-light of which was the lamentable fact that water supply was so inadequately appreciated until there was some interruption of service or catastrophy. He pleaded for a greater appreciation of the public for the services rendered by water works engineers and operators.

Highly interesting and entertaining, was a "Travel Talk" by W. T. Randall, Canadian Manager for Neptune Meter Company, who had recently returned from South Africa where he arrived with the Russian Ballet and left by way of Zulu Land, where the women do all the work and where sanitation and cleanliness were more impressive than in parts of civilized South Africa. Between lion hunting with a camera, flying over Victoria Falls and dodging big snakes, it was reported around the rooms that Mr. Randall obtained orders for 4,000 meters, but it was not clear how many went to the Russian Ballet or how many to the Zulus.

Closing Banquet

Gay but orderly was the Annual Banquet followed by a floor-show put on by the Canadian Water Works Equipment Association.

During the dinner a memorial on the late Wm. Gore, eminent consulting engineer of Toronto and long a valued member, was read by W. E. McDonald of Ot-

Norman J. Howard, Director of Purification, Toronto (AWWA Director from Canada)

A. E. Berry, Chief Engr., Ontario Dept. of Health (Secy. and A.W.W.A. Director-Elect)

W. L. McFaul, City Engr., Hamilton, Ont. (Honored as Past-Chairman)

M. Pequegnat, Mgr. Water Comm., Kitchener, Ont. (Past-Chairmen of the Section).

tawa. To the family of the deceased was presented the certificate which memorialized the late member as a leader of the profession. To W. L. McFaul, City Engineer of Hamilton, was presented the "Immediate Past President's Certificate" as is the custom of the Section in recognition of outstanding services rendered it.

The speaker of the evening, Dr. Wilfred Bovey, of McGill University, set forth some ancient and little known history of water supply engineering, when he traced water works developments back to 1,500 B. C. It was especially interesting to learn that the first water supply engineer, whose fame spread rapidly, was a Greek named Eupalinus. He constructed a supply system for Magara (Isthmus of Corinth) in the year 700 B. C. and, according to Dr. Bovey, immediately the city grew in power and importance until it was a leading city of Greece. Eupalinus thereby gained international fame, for he was sent for by Polycrates, dictator of Samos (they even had those 700 B. C. also) and for Samos, on the Agean Sea 180 miles distant, Eupalinus built even a finer water system. The next event making water works history was the Roman Aqueducts and then in 1582 Peter Morris put in the famous London Pump. Then, Dr. Bovey skipped many years to local water works history beginning with the Montreal water-haulers and thereafter (1801) the first Water Works Pond—a gravity supply privately operated. The company failed along with the wooden pipes, and then a second company lasted 13 years. The third company installed a 14 H.P. pumping engine at the river but the service was so inadequate that it was bought out by the city in 1845. Then came the famous 1852 report of the expert water engineer, T. C. Keefer, much of which, Dr. Bovey said, proved as sound advice today as when written 85 years ago. Keefer persuaded Montreal to build a 5 m.g.d. (admittedly over sized) system but predicted growth and benefits to the city if beautified to attract tourists. (Subsequent history of the Keefer system and Montreal's Water Works since, was the subject of presentation by C. J. DesBaillets, which appears later in this report.—Ed.)

Officers Named

The following were announced, elected as officers for the ensuing year: Chairman—E. V. Buchanan, Engr.-Manager, Utilities Comm., London, Ont.; Sec'y-Treas.—A. E. Berry, Chief Engr., Provincial Dept. of Health, Toronto; Trustees—A. D. Stalker, Ass't Water Engineer, Ottawa; G. H. Strickland, Superintendent Filtration, Windsor, Ont. Member of A.W.W.A. Board of Direction from Canadian Section—Dr. A. E. Berry. Note: Trustees carrying over are—C. J. DesBaillets (Montreal); A. B. Manson (Stratford); C. E. Brown (Meaford); L. G. McNeice (Orilla). The term of N. J. Howard (Toronto), as Member of A.W.W.A. Board, runs through the National Convention in June.

Inspection Trips

An afternoon was devoted to an inspection of the Montreal Filtration Plant, Pumping Stations and Reservoirs. A post-convention trip was taken to Jenkins Bros., valve plant, where luncheon was served members and guests—many of which took the opportunity to visit the Water Works of nearby Lachine.

The ladies had many trips to points of interest in and around the city.

Technical Sessions

(Chairman, F. P. Adams, Presiding)

"Boiler Feed Water Treatment," by JAMES O. MEADOWS, Engineer, J. T. Donald and Company, Montreal.

Mr. Meadows discussed the causes of scale formation, other undesirable characteristics of boiler feed waters, and methods of correction by external and internal treatment. For the latter maintaining 40 to 100 parts per million soda-ash in excess had been most successfully used as also had sodium aluminate. Lately, organic glucosides (tannin extracts) and chrom-glucosates had been more generally used in combination with alkali—especially sodium phosphate. In lime-soda treatment, aided by coagulants, the chemicals added all at one time received a 45 minute spiral mix downward through a central drop pipe to the bottom of the deep circular up-flow tank, providing 6 hours detention and up-flow of not more than 8 ft. per hour. The hot process was preferable in being speedier and, thereby, allowing reductions in the size of plant. Also, more crystalline and filterable precipitates were produced without the need for excess chemicals.

In discussing Zeolite softening, Mr. Meadows considered the process, on the whole, most satisfactory for

Three of the Section's Trustees

M. W. Rogers, Mgr. Water Works, Carleton Place, Ont.; L. G. McNeice, Engr. of Water Works, Orillia, Ont.; H. G. Strickland, Supt. Filtration, Windsor, Ont.

C. J. Des Baillets, Chief Engr. Montreal Water Board (Convention Host—has done much for Montreal's Water System).

Theo. J. Lafreniere, Chief Engr., Quebec Prov. Dept. Health (Proud of water supply progress in Quebec).

waters low in hardness and those high in sulphate hardness. It was frequently advisable to pre-treat with lime-soda and finish through a zeolite unit. Thus, the total solids and sodium salts could be held down. To control pitting the removal of dissolved oxygen, to leave less than 1 p.p.m., was also an important consideration in modern boiler water preparation. With such low dissolved oxygen, waters became non-corrosive at pH 9.5.

Some time was devoted to the so-called "Scale-Buoy" which is a sealed glass container partly filled with mercury. Mr. Meadows read excerpts from reports of investigations, by others, which failed to show the advantages claimed by proprietors marketing the Scale-Buoy. When shaken in the water it is said to emit electrical charges—such charges exhibiting an effect which causes loose sludge like deposits rather than the otherwise tenacious hard-scale. It also reduces soap consumption where successful.

N. J. HOWARD (Toronto) in defense of "Scale-Buoys," said that regardless of theory and laboratory studies there were several installations reported to be producing results of worth. He cited experiences of the Canadian Pacific Railway with Scale Buoys in engine tenders, and the Paige-Hersey Company of Welland, as well as others, who had testified to the practical effects of the mysterious Scale-Buoy. In his own experience hard scale had actually disintegrated and left the metal surface clean in a water still. However, in another case there had been no benefit. Restaurants had also benefited by placing miniature Buoys in their coffee urns to prevent depositions.

M. PEQUEGNAT, Superintendent, Water Commission, Kitchener, said that Scale-Buoys had cleared the scale from the boiler tubes of Kitchener's sewage plant. So thoroughly had it done so, that leaks resulted. In his home the household size Buoys had been effective in softening laundry and bath water. Strangely, it was not of much benefit, according to his wife, in dish washing.

MR. MEADOWS in closing, said that he had presented the reports on Scale-Buoys for their worth. Admittedly one should not lose sight of practical experiences, and opinions should not be formulated precipitously.

"Treatment of Organic Colored and Corrosive Waters" —By N. J. HOWARD, Director of Water Purification, Toronto, Ont.

Mr. Howard's paper constituted a valuable summation of what has been learned in recent years concerning the most effective and least costly methods of removing organic stain from water and rendering the finished product least corrosive. In non-technical language, his presentation was clear and understandable to engineers and managers, as well as chemists. He spoke of the ease of coagulating old (aged) color as compared with fresh color, and the usefulness of pre-chlorination in artificial aging of resistant colloids, including coloring matter. The latter, being most effectively coagulated in the acid zone (pH 4.0 to 5.5), the use of ferric iron salts had distinctive advantages in color removal. Chlorinated-Copperas, in particular, had proved an effective inexpensive iron salt, with ferric chloride and ferric sulphate being employed also. In iron coagulation, pre-chlorination had been an added value in preventing dispersion of the iron and its reduction to the ferrous form.

In difficult cases, Mr. Howard said that stage coagulation had been of benefit, both taking place in the primary mixing device. The first stage a rapid acidic coagulation was followed by addition of more coagulant and an alkali to effect secondary coagulation at higher pH values (6.5 to 7.0). For this purpose filter alum and soda ash or lime, or sodium aluminate, seemed most effective. Beyond the optimum pH increase for best coagulation and floc settling, any additional alkali for corrosion control should be withheld for application beyond the filters. He referred to the possibilities of color removal by super-chlorination, followed by dechlorination through granular carbon filters. In very difficult cases, coagulation, aided by permanganate in conjunction with pre-chlorination, had been reported efficacious.

"Experiences in Color Removal at Ottawa," by H. P. STOCKWELL, Chemical Engineer, in Charge of Filtration, Ottawa, Ont.

Mr. Stockwell in reviewing experiences and developments in operating Ottawa's filtration plant, stated that color removal from the Ottawa River water was the chief problem. Spending $34,000 annually for alum as coagulant, the mixing period was 40 minutes followed by 3⅓ hours settling. Filters had been sufficient to operate at 50 per cent of standard rate of 2 gal. per sq. ft. per min., but even so floc penetrated the beds and eventually reached the effluent. Floc formation and color reductions had been best between pH 5.5 and 6.1, but the original scheme of treating to reach an optimum pH had been displaced by total alkalinity measurements as the principal criterion. Likewise, a study of the chlorine demand of filtered portions of coagulated water had proved a valuable guide in obtaining the most effective coagulation. Addition of lime ahead of filtration had proved impractical. Control of filter washing had been materially improved by employing a small observation unit to determine rate of bed penetration and most effective wash program and rates. All filter beds were being treated semi-annually with heavy dosages of chloramine to sterilize and loosen the coatings on the sand grains. Lime application to the filtered water raised the pH to

W. E. MacDonald, Ottawa's Engr. of Water. (A Past-Chairman of the Section and a "Wheel-Horse.")

Ross L. Dobbin, Peterborough's Manager of Utilities. (Past-President of A. W. W. A., Divan Medalist, Honorary Member.)

Snapped on the Inspection Trip

1. Fiegehen, Kinney, Netbery from Toronto; 2. Charlie Richardson, Builders Iron Foundry Chief Engr., two members and two pipes; 3. Ornate Entrance Foyer Montreal's Low Level Pump Station; 4. In Canada Do as Canada Does—Jim Kinney, Wallace & Tiernan Canadian Manager, and Harry Jordan, A.W.W.A.'s Exec. Secy., Light Up a Pair of Dunhills. Harry's Was Presented to Him by the Indiana Section—Jim Kinney Had a "Good Year" Too.

between 8.4 and 9.1, as the marble test for corrosiveness indicated, required. Between 0.6 and 1.0 grain of wood burned lime (93% CaO) had been the amounts needed.

Mr. Stockwell told of rapid onset of sludge putrefaction in summer, requiring basin washing at 3 week intervals. In checking putrefaction, powdered carbon had been a decided help. He also told of taste troubles experienced during severe weather when mains were freezing. Apparently the ice had disrupted lime film deposits on the interior pipe walls. Reducing the pH proved of help, but red water at hot water taps resulted in new complaints.

MR. MEADOWS (Montreal) spoke of a problem of color removal which had given considerable difficulty. Faced with high color and alkalinity of only 5 parts, the alum floc settled very poorly at pH 4.8 to 5.0, and filter effluent was hazy with the residual alum present. He asked for a possible suggestion.

L. H. ENSLOW (New York City) said he would attempt it. He reviewed the mechanism of floc formation in color removal, which he referred to as "lake" formation similar to dye settling in textiles. This meant that the work performed by the coagulant was entirely different from that in turbidity removal or softening. The more the color present, the lower the pH zone of effective "lake" formation, and the older the coloring matter the simpler the task. The fact that ferric iron was more effective on many colored waters could be explained in the lower solubility of the iron complex formed (the iron "lake") as compared to that from aluminum compounds. He credited Dr. Hale of New York's Water Department with having some years ago studied and reported on water decolorization phenomena with coagulants. The composition of the "lake" production accounted for the less alkalinity required per pound of coagulant and, likewise, the fact that alkali added dispersed or prevented the color compound from forming properly—some called it "color-setting." Of considerable interest to him, said Mr. Enslow, was the Ottawa method of determining effective coagulation by making chlorine demand tests, which in effect was a detection of the extent to which reducing colloids (including organic color) remained unprecipitated. It was just this that explained the mechanism of pre-chlorination. It was the oxidizing effect on such reducing compounds that gave the resultant value in more effective or economical coagulation. It must be appreciated that materials such as tannin or leaf and bark infusions were distinctly dispersing or peptizing—*i. e.*, were anti-coagulants, and especially so in the alkaline zone. The presence of negative or acid ions in abundance was a distinct asset in color clotting and therefore some benefit might accrue from adding neutral or acidic compounds—never alkaline ions. Mr. Enslow said that he did not gather whether Mr. Howard had knowledge of the actual employment of super and dechlorination for color destruction (Bleaching) or was merely advancing the idea as a possibility. In either case he would say that the scheme had been proven and was put to actual use on small supplies by International Filter Company of Chicago.

MR. HOWARD replied that he based his opinion on some experimental work wherein with 3 parts of chlorine a color of 60 parts had been removed. He pointed out that the criterion was not the dosage of chlorine but the residual and contact. It was interesting that the higher the chlorine dosage the greater had been the disappearance of the excess chlorine, indicative of the mass law effect in chlorine attack on organic substances.

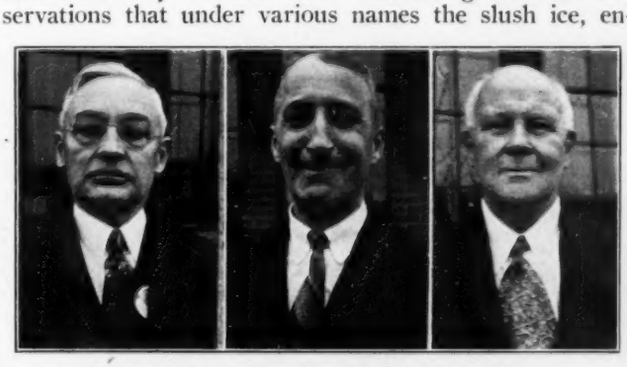
MR. MEADOWS, rose to say that he had tried super-chlorination on the water in question, and with disappointing results. However, the dosage employed and residual carried proved to be less than might be considered super-chlorination. Mr. Enslow replied that one could not predict that even super-chlorination would prove practicable in Mr. Meadows' problem; but, if tried again, should be carried somewhat further to reach a conclusion. Three factors entered—to wit; residual chlorine, temperature, contact period. And, there was a possibility that pH and light might prove secondary considerations.

WILLIAM STORRIE, Consulting Engineer (Toronto), who had been consultant on the Ottawa design, said that nowhere had the value of constructing and operating an experimental plant been so pronounced in final design and process selection as at Ottawa. To him a pilot plant was an investment of great merit.

Intake Ice Problems

"Frazil Ice Problems in Pumping Stations," by ROBERT DORION, City Engineer, Lachine, Quebec.

Mr. Dorion discussed the formation and behavior of frazil (snow) ice in streams and lakes, its behavior, difficulties encountered at Lachine and method of correction eventually worked out. Interesting was the observations that under various names the slush ice, en-



"Wheel-Horse" in Montreal's Water Dept.

F. W. Dorrance, Engr. of Constr. and Distribution; A. Kilpatrick, Filtration Engineer; J. H. Harrington, Chief Chemist.

Read Papers

Robert Dorion, City Engr., Lachine, P. Q.; H. P. Stockwell, Chemical Engr. Ottawa's Water Dept.; Jas. O. Meadows, Consulting Sanitary Engr. and Chemist, Montreal.

countered in water works intakes, was all the same thing. At night it settled to lower depths and in the day rose to the surface. At Lachine the pump well screens had become blocked and later the 3 ft. diam. gravity steel intake line 10 ft. below water sur...e had become choked. Temporary expedients had been tried with indifferent success, including running steam lines through the intake. As the best overall permanent relief an auxiliary 12-inch pump discharge had been connected into the intake pipe and a large gate installed to close off the intake at the pump well. By closing the gate and starting the pump slush ice in and around the intake was blown out as frequently as necessary. (If this digest of Mr. Dorion's valuable contribution does not do his paper justice, it is because of the difficulty in following a fast reader, of a short and meaty paper, accustomed to reading and speaking in Canadian French.—Ed.)

"Functions of the Quebec Streams Commission," to be presented by O. E. BOURBOUNAIS, Chief Engineer of the Commission, was read in his absence by Mr. Gill, an associate, who expressed the regrets of the author. The Commission was established in 1911 but was without engineering staff until 1913 when stream surveys and gaging was started. Now all major Quebec streams had been studied and records were available. The major activity of the Commission had been the building of dams and reservoir systems to supply water to industry for power production and processing, the cost of operation and financing being pro-rated to industries served. In one instance a single company had been served by the Gataneau River development and stood all costs alone. Reservoir system had been established on several streams, the more extensive works being on the St. Morris (680,000 H.P.), the St. Francois and the Gataneau.

DR. O. LEFEBVRE, a past president of the Engineering Institute of Canada, said that in Canada all water rights were held in perpetuity as the property of the Crown and the practice of selling rights prior to 1927 had been stopped. Now such rights were leased 40 to 75 years. The reservoir schemes developed by the Commission had been on a self supporting basis with $750,000 guaranteed (pro-rated) annual return on $10,000,000 invested for the benefit of the industries of Quebec.

The Water Works of Montreal

C. J. DESBAILLETS, Chief Engineer of Montreal's Water Board, reviewed the interesting history of the Montreal Water Works, which after many ups and downs had been purchased from the private proprietors in 1845. Interesting was the fact that prior to the establishment of the three-member Water Board in 1920 there had been a disastrous strike of water works employees who did considerable damage to pumps and broke numerous fire hydrants. The result was that the city was without a vestige of water or fire protection for 4 days, during which time bankers and lawyers became coal heavers and repair men, or any other thing to get water service back into being.

Mr. DesBaillets then described the Montreal works of today, consisting of 300 m.g.d. filter plant capacity (half rapid sand—half slow sand); and chlorination by electric-eye automatic control through specially designed equipment. The pumping stations served low level, intermediate and high level districts through 6 service reservoirs floating on the pumps. However, the reservoirs all told held but a 12-hour supply (100 m.g.), representing a weakness which a program for enlargement to 350 m.g. and consequent smoothing out of pump operations, was designed to correct.

Water-hammer had been successfully eliminated at all pump stations through the use of Larner-Johnson streamed Lined Needle Valves, properly adjusted as to closing speed. In recent years 24 to 48 in. trunk mains had been laid with reinforced concrete pipes. As to operating costs; filtration and chlorination in 1936 averaged $1.61 per m.g. of which 53 per cent represented wages and salaries and 47 per cent for supplies and electric current. Pumping costs for low level service had been $4.75 per m.g. and intermediate service $5.49. In addition to reservoir enlargements, plans were under way to extend the supply intake further from the shore line to take water having less pollution.

F. Y. DORRANCE, Engineer in Charge of Construction, in reviewing construction developments, said that joint compound used in recent years had proved more satisfactory than lead, and had saved $40,000 to $50,000. Experiences had shown the value of cleanliness in preparation of the joint, the bell and spigot being actually cleaned with gasoline and care taken to keep out clay and dust. The care had paid in effectiveness of joints.

Round Table Topics

"Fire Protection Charges" was the topic introduced by Ross L. DOBBIN, Manager Utilities, Peterboro, Ont., who summarized the information collected by the Canadian Water Works Information Exchange. Hydrant rental varied from $2.00 to $80.00 per hydrant—the average being $40.00 and representing 46 cents per capita. In Peterboro the cost of fire protection was evaluated at 33 per cent of the annual costs of the water utility, which compared with 36 per cent in Toronto. No private fire protection charges had been established because tax payment proved sufficient to meet costs. If not the case, private charges were justified.

The Chairman said that where the water works had been operated under Utility Commissions more adequate

From the Maritime Provinces

A. A. Laflin, Supt. Water, St. Stephen, N. B. (Has an international plant supplying both sides of the border.); R. D. McKay, Engr. Provincial Health Dept., Nova Scotia, Halifax; J. S. MacMillan, Mgr. Water Works, Charlottetown, P.E.I.

charges for fire protection had been the rule because they had the power to set rates. However, they had no power to enforce payments if the Council refused to pay such rates.

MR. BUCHANAN (London), believed that the nearest approach to a correct figure for fire protection was to set up a hypothetical system sufficient for supply service only and deduct its estimated cost from the value of the existing system. The difference was the figure to be used as the base in calculating fire service charges. If such a method be adopted, London's hydrant rental charge would be more nearly $55 than the $18.00 allowed the water utility. On the other hand the tax payers owned the system in the last analysis and he questioned that the method of paying for fire protection made much difference in the final analysis.

WM. STORRIE (Toronto) thought that the per capita method of charging for fire protection was probably the simplest and most practical. Hydrant rental plans had weaknesses and the inch-foot main rate was not readily understood by Councils.

Service thawing was performed with a fleet of 5 electric generator type portable thawing units, owned by the Water Department. Service thawing, in consequence, was no longer a major problem. During the past winter it had cost only $1.70 per service thawed in 3 to 10 minutes, as against the average of $3.30 reported by Canadian cities in the Water Works Information Exchange. In an average winter 900 services, 30 mains, 2,000 hydrants and 100 valves had to be thawed.

Mr. MacDonald told of experiences with many taste complaints during periods of ice ring formation in mains, and following service thawings. Presumably the ice had stripped some of the organic deposits (lime film and tubercles) from the walls and bottoms of the pipes. Reduction of the lime treatment for corrosion control had seemingly bettered the taste. To preclude street ice danger due to hydrant flushing, they had used hose run into sewer manholes and flushed at night only in business districts.

R. H. MARTINDALE, Superintendent Water, (Sudbury), reported troubles with hydrant heaving and shearing off at the lateral connection until wrapping the barrels, with heavy asphalt roofing bound on with wire, and the hole filled with sand. Frost-casings had been found of questionable value. Mr. MacDonald commented that experiences in Ottawa had shown frost-casings worth while.

Caught by the Camera at Montreal

1. "Dick" Williamson, Canadian Industries, Ltd.; 2. Henry Hadley, City Engr., Verdun, P. Q.; 3. P. Bromilow, Montreal Water Board; 4. O. E. Scott, Mgr. Utilities, Belleville, Ont.; 5. A. E. Ditchburn, Mgr. Utilities, Strathroy, Ont.; 6. Wm. Tate, Supt. Water, Picton, P. Q.; 7. Jack Diven, The Leadite Co.; 8. D. A. Pritchard, Vice Pres. Canadian Industries, Ltd.

W. P. REDFERN, Toronto Consulting Engineer, believed that when the water utility paid interest on its debentures it should be allowed a fair rate to cover fire protection. With a proper study to apportion the cost of the system between fire service and utility service (cost of mains being the most important difference), proper charges could be set up. On a hydrant rental basis the figure generally would be between $50 and $60 per hydrant.

"Frost Control and Cold Weather Operations" was the topic introduced by W. E. MacDonald, who recited experiences and practices wherein frost penetration observations had revealed the ground frozen to depth of 7 ft. 6 in. whereas in earlier years 5.5 ft. cover had been ample. Fire hydrant flow tests, frequently made in danger weather, had served to reveal the rate of ice ring built up from the pipe wall inward. By introducing steam from self contained thawing trucks, and reversing the cross flow through certain sections of the grid system, growth of the ice ring had been checked with some success. Hydrant laterals were protected with felt insulation and where possible a tap was provided and service lines taken off from the laterals. As to hydrants: Employing eleven men, all important hydrants were inspected daily during danger periods, and hose connection caps left loosened; all hydrants being inspected at least twice weekly. All important gate valves (roughly 600) were in pits electrically heated or steamed each night. For emergency service a truck with steam boiler answered every fire alarm during the danger period, in readiness to thaw hydrants. Continuous information was supplied the Fire Department to insure the use of the most effective hydrants.

Asked for his opinion as to the cause of tastes during main and service freezing, L. H. ENSLOW said that this situation was not new to him. He had before heard of complaints of very foul odors coming on the heels of fronzen mains and services thawed electrically. He believed the trouble due to disruption of the pipe slime and encrustations or tubercules, and possibly from the flow of electric current and heating of the pipe walls. He could only believe the lime reduction and taste improvement a coincidence. The slime deprived of oxygen, due

W. S. Lea, Montreal Consulting Engineer; Wm. Storrie, Toronto Consulting Engineer; Chas. Johnson, Supt. Water, Verdun, P. Q. (Oldest of Quebec's Water Superintendents. He Operated the Province's First Filtration Plant.)

to the ice ring seal against the wall, probably produced the same putrescent condition as noted in shallow streams and ponds covered with an ice blanket preventing re-aeration. None of this was helped any by the crushing and, later, the scraping by the loosened ice ring or chunks of ice. It could be likened to pipe cleaning operation, with the consumer on the receiving end. Complaints, in U. S. cases, of the water "smelling like a sewer" indicated the foulness of the scoured off main coating and it probably had a metallic taste as well—imparted by iron sulphide. Another experience of interest followed the dewatering of a long main incident to repairs. Since return to service, after being empty for 10 days, the water had continued in bad condition (turbidity and soluble iron) for a considerable period and flushing had not cleared it up.

(At this point, Mr. Buchanan, the Chairman Elect, took the Chair.)

"Accounting and Record Keeping" as discussed by A. B. MANSON, General Manager, Utilities Commission, Stratford, Ont., revealed Stratford practices where the electric, gas and water utilities came under one organization, thus making for efficiency and economy in meter reading, record keeping, billing. Water services were 93 per cent metered, with all meters in basements only. One reader covers 200 meters daily (50/50 water and electric) and reports abnormal readings promptly for immediate follow up.

Bills, mailed promptly, reached domestic consumers bi-monthly and large consumers' meters were read weekly or less frequently, as the case warranted, but billed monthly. Mr. Manson then covered in some detail the mechanics of the accounting operations and equipment involved. In reply to a question, he stated that the accounted for water could not be given because there was no checking of the water pumped against metered consumption. On this, Mr. Pequegnat reported that, with complete metering, Kitchener, Ont., could only account for 70 to 75 per cent of water pumped. And, Mr. Buchanan said that London's (Ont.), record was 75 to 80 per cent only. In reply to questions, Mr. Manson said that contract was always with landlords, who paid meter damage. Questionable takers and tenants had to maintain guarantee deposits. If requested by landlords apartments were metered separately. In similar cases, London required separate piping to such apartments.

Water Works Systems of the Maritimes

"The Supplies of Nova Scotia" were in part briefly described by R. D. MCKAY, Sanitary Engineer, Provincial Department of Public Health, Halifax, Nova Scotia, who reported 43 public supplies in the Province of which 8 employed water treatment. The Provincial Health Department provided monthly examination of samples from each cooperating system. In describing several of the systems serving populations of 2,500 to 3,000 Mr. McKay named each by initials only, probably for reasons that both approval and condemnation of design, operation and maintenance were set forth. The chief problems in Nova Scotia were algae growths and cross connections, specific failures in the latter being cited.

"The Water Works of St. Stephen, New Brunswick," was described by A. A. LAFLIN, Superintendent of Water, St. Stephen, N. B., who reviewed the history of the system installed by the Main Water Company in 1885, purchased in 1905 by the city and revamped under F. A. Barbour of Boston, Mass., as engineer. The surface supply and filter plant were abandoned and dug wells 30 ft. diam. and 20 ft. deep were put down in the St. Croix River Valley yielding 1.5 m.g.d. safe yield of pure water at 6 ft. max. draw down—this being twice the average consumption of 750,000 g.d.p. Storage facilities consisted of 1 m.g. covered reservoirs at each end of the system. The St. Stephen system might be called an "International System" inasmuch as it served Calais, Maine, also. Since 1930 the system had been 100 per cent metered. With $250,000 (1946) bonds outstanding $176,000 in the sinking fund gave St. Stephen a comfortable position in water works finances.

"The Water Works of Charlottetown, Prince Edward" was described by J. A. MACMILLAN, Manager of the Charlottetown 3-member Water Commission which had had but 16 commissioners in 50 years, the present members having served 10 years or longer. Dating back to 1887 the system, serving 15,000 people through 3,000 services, consisted of dug wells, with all pumping equipment in duplicate and twin mains from a tightly covered reservoir, at total cost of $500,000 of which $300,000 had been retired. With fixture rates, and the larger consumers metered, the system had yielded profits turned over to the city quarterly. However, there was a requirement that such surplus could only be devoted to water works or sewerage purposes—the sewerage system also being under the Water Manager. Pleasant climate, and not a frozen main in 50 years, was the boast of Charlottetown.

The meeting came to a close with the presentation of **"Drought Experiences of 1936 in Ontario"**—By DR. A. E. BERRY, which revealed the effects suffered by Southwestern Ontario, during the severe short drought of extreme temperatures, which resulted in the most severe conditions on record for the section during the period May to September. July, with rainfall 27 per cent of normal, was the worse month. The flow of one river, carrying sewage of 6 municipalities, was practically 100 per cent sewage effluent when the normal flow of 400 c.f.s. had dropped to but 47 c.f.s. Another important river carrying sewage of two municipalities had dropped from 632 c.f.s. to 38 and 36 in July and August. High temperatures and rapid evaporation made stench-pots of such streams. The surface water supply of Dundas failed completely, requiring tank car importation and pumping of heavily chlorinated auxiliary supply into the mains for sanitary usage and fire protection.

MR. STORRIE (Toronto), rose to say that it seemed propitious to back the setting up of a Provincial Stream Authority in Ontario and the development of a water conservation and sewage disposal program. He thought the proposals of the Grand River Commission should be checked over by such a central authority, to prevent pit-falls and waste of money in its proposals concerning stream regulation and pollution abatement by a reservoir system for dilution.

F. P. ADAMS (Retiring Chairman), as Secretary of the Grand River Conservancy Commission, wished the members to appreciate that the original program of the Commission had started as a flood control undertaking some years back. Now it was the drought that focused attention on its proposals. While having no intention of discouraging or throttling treatment of sewages there was definitely a middle ground best served by a combination of flood and dilution control along with adequate but economically sound treatment of sewages. Further, industrial water and wastes treatment and dilution were additional considerations. Whereupon, Mr. Storrie explained that he had not intended reflection, but thought that all such undertakings should be in liaison with a central authority.

(Adjournment)

SOME CONSIDERATIONS IN DESIGNING SMALL SEWAGE TREATMENT WORKS

By W. B. WALRAVEN

*Consulting Engineer**
Springfield, Ill.

WHEN we see the great works which have been built for the disposal of sewage from our larger cities we are lost in amazement at the technical skill which brought them into being. To the planners and builders of these monumental works we figuratively doff our hats—they represent the foremost in the sanitary engineering profession.

Yet when I visit a miniature treatment works in a small town, struggling under the dual handicap of insufficient design and semi-trained supervision, I sometimes believe that the designers of these small plants have to exercise more ingenuity than is required for the creation of the larger plants.

If the works be built by special assessment one will find that higher assessments may be levied within a city than in a small town, not from the legal standpoint, but from the standpoint of factual experience. The same general line of reasoning applies also with regard to sewer rental charges. We therefore find that there is more money per capita available for treatment works in the larger towns and cities, regardless of the methods of finance. Under conditions at all comparable, the designer of the small treatment works finds that he has less money per capita with which to build and finds also that the per capita costs are higher—a dilemna with two horns. Consequently, he is always having to use his ingenuity to devise new ways of accomplishing his purpose with the money available—especially when realizing that every part of a small plant costs more per unit of capacity than is true of larger plants.

After a tentative layout is made for a plant, nicely balanced in all its units, the engineer makes his first estimate of cost. Usually he discovers that his plans are bigger than the municipal pocketbook, and he must scale down the size. The designer of a large plant finds that he can trim the cost by omitting units here and there and still retain sufficient capacity and flexibility.

But picture the events taking place in the office of the little-known engineer designing a plant for a small town. In the first place he knew in advance that the funds available could not possibly pay for a plant really adequate in size. Consequently he calls upon the State Sanitary Engineer and begs to learn the absolute minimum requirements of the Department of Public Health. Then follow days of bickering, recriminations and heartaches, with the State Sanitary Engineer torn between his duty to maintain safe and resonable standards, and his knowledge that it is better for the community to have a somewhat inadequate plant than to have none at all. Eventually a compromise is reached, but still the designer knows that the money will not stretch far enough. So he redesigns the details, hoping to save a little on materials, then combines the two primary tanks into one having a gross capacity equal to the two—but at a loss of flexibility.

Single handed through it all he fights his way against great odds, pleading with the State Sanitary Engineer, and changing the specifications to arrive at less costly construction, until at last the little plant is completed and put into service. Strangely enough it functions, turning out an effluent not markedly different from the effluent from the great plants.

Basis of Design

In the design of small sewage treatment works, the most important item is to arrive at a proper determination of the present and the probable future flow, but generally speaking the engineering fees are too small to allow the proper amount of preliminary investigation. In many instances engineers, in the absence of metered water records will predicate the volumetric design of the tanks upon an average flow of 100 gallons per capita per day, with a suitable allowance for future population increases and then allow 50 per cent excess for peak flows under normal conditions. If it should happen that the actual flow is only 50 gallons per capita per day, which is often the case in the smaller communities, then the primary tanks are needlessly large as compared with the other units. This is bad practice for more than one reason. In the first place the excess cost of the primary units takes money which ought to be used elsewhere. In the second place, too great capacity (and consequently too long retention in the primary tanks) may and often does permit the sewage to become septic before reaching the secondary processes, thus putting an unnecessary burden upon other units, already pinched in the design.

In small communities it is almost universally found that the fluctuations in flow are much greater than with large cities. This leads to the conclusion that the small plant should have greater flexibility, but there is scarcely ever the money available to provide that flexibility. Then too, a small industry such as a creamery, a brewery, or a packing plant, may deliver a waste which is staggering in proportion to the domestic wastes. Large communities are much less subject to high ratios of industrial wastes to the domestic sewage. However, exceptions to this statement may be found in Illinois, notably at Decatur and Peoria.

Most of the smaller communities use less water per capita than is used in the larger cities. Consequently the designer of the smaller plant should know that the volume of sewage will usually be lower and the concentration of solids higher. Then too, it is usually found that in the absence of long detention in lift stations the sewage from the smaller town is less likely to be septic when received at the plant, due of course to the shorter length of time required for its flow from the place of origin to the treatment works. All of these factors should be analyzed carefully before attempting to design the various units, but more often than not are given only hasty if any consideration.

It may not be generally known to engineers, but the State Division of Sanitary Engineering stands ready with its laboratory equipment and personnel to aid in

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the examination of sewage flow and characteristics, and we should all take advantage of these facilities when questions arise.

Choice of Process and Units

In planning sewage treatment works, the engineer must weigh carefully the merits of the several types of treatment from the standpoint of their applicability to the particular situation. The major consideration in the small community is to have the plant as nearly fool proof and as simple to operate as possible.

The activated sludge process appears definitely to possess an advantage in most large installations. However, it is not as yet very popular in small cities, although we can cite excellent examples to the contrary. An activated sludge plant requires somewhat more skill to operate, and such skill as is not ordinarily available financially to the small town. A sprinkling filter may be operated more easily and will stand far more abuse. So far as first cost and annual cost are concerned, local conditions are of major importance, but in general there is little choice on an overall cost basis between these two types in the smaller installations. Operated with competent skill, the activated sludge plant will undoubtedly produce a better effluent than the sprinkling filter, but the sprinkling filter has more to recommend it as a unit less subject to loadings variations and operating niceties.

Chemical precipitation plants are coming into vogue for certain large installations requiring only an intermediate degree of treatment, but are not as yet generally applicable to smaller communities unless the process be a seasonal one to relieve loadings on biological processes.

Intermittent sand filters are sometimes used although their adaptability to general use is questionable. It may be stated, without fear of successful contradiction, that the intermittent sand filter costs about as much to build and maintain as do the more usual types of treatment, and has the very serious disadvantage of being inoperable during freezing weather.

Primary Units

In choosing the type of primary sedimentation unit for the small municipal plant, usually the field is quickly narrowed down to a choice of Imhoff tanks or primary clarifiers with separate sludge digestion tanks. The Imhoff tank has many admirable qualities foremost of which is that normally it requires little attention—that is, when the digestion compartment is on good behavior. Units built sufficiently large, have been known to "run themselves" for long periods without a great deal of attention. However, when things go wrong with the digestion processes, an Imhoff tank appears to be a sorry piece of apparatus. The engineer should realize that certain types of sludges, particularly from industrial wastes tending to create either too great alkalinity or too great acidity in the digestion chamber, may upset the upper, or flowing through compartment with disastrous results. This condition is likely to result when small plants try to handle milk products or brewery wastes. However, the Imhoff tank when behaving well, solves the vexing supernatant liquor problem encountered in separate sludge digestion tanks. Generally, the digestion compartment of an Imhoff tank should have greater capacity than is required in separate sludge digestion tanks, because of the impracticability of heating Imhoff tanks.

Odor nuisance is far less prevalent with separate sludge digestion tanks than with Imhoff tanks. The separate sludge digestion tank also lends itself more readily to the trapping and utilization of the gases of digestion.

The usual alternative is to design primary sedimentation tanks with or without mechanisms, and to handle the sludge in separate digestion tanks.

It may safely be stated that no plant should have less than two primary settling units, even though a single unit of equal capacity can be built more cheaply. It is equally safe to say that digestion tanks should also be in duplicate, unless adequate provision is made to lagoon bad supernatent liquor or foaming sludge. For primary sedimentation there is a measure of choice between flat bottom tanks with mechanisms, and hopper bottom tanks without mechanisms. However, it is my belief that the tanks with mechanisms produce so much the better operating results as to justify their recommendation for the smaller installations. For secondary settling tanks, and particularly following activated sludge, it is considered essential to provide mechanisms, even though one may point to the successful operation of hopper bottom secondary tanks in instances. Here duplication of units is highly desirable for most efficient operating.

Details

An almost endless discussion would be required to cover the subject of details of design. Capacity and choice of units are certainly of great importance, but as in other walks of life, "it is the little things that count." A poorly balanced plant and even an insufficiently large plant may be operated reasonably well, provided the details are arranged so that adjustments and changes may easily be accomplished. A good plan for the designer to follow is to put himself into the position of the operator, to go around mentally with him and to perform the actual duties required to make the plant run. It is in the manipulation of minor parts that the operator makes an abstract set of plans into a working reality. An engineer cannot design a plant so as to be self adjusting but he should leave it so that the required adjustmets may be made with a minimum of effort.

In a general paper, little can be said about size and capacity of units, but as was pointed out above, such factors as the presence of even a small industry delivering an organic effluent, the low water consumption of small towns, and the greater fluctuations of flow from hour to hour, all must be taken into account before attempting to design. Omitting consideration of industrial sewage, because that is a problem unto itself, I have certain definite and possibly heretical beliefs about capacities For a small community, where necessary to cut costs to build a plant, I would reduce the primary sedimentation units to the very minimum allowed by the State Sanitary Engineer, and use the money thus saved for the enlargement of the units involving the biological processes. I would also save enough money to provide what might be termed the niceties,—ample grounds, illumination, sidewalks, some planting and shrubbery, to attract favorable comment from visitors and taxpayers.

Good design calls primarily for duplication of units and flexibility without sacrificing simplicity. The smaller the plant, the harder it is to satisfy these requirements because of lack of funds, but unfortunately the small plants should be designed more carefully than the larger ones. The reason for this is that the operating personnel in the larger plants are more highly trained and therefore more able to make the correct alterations.

The Importance of Baffles

Improperly designed influent details are probably the cause of more imperfect operation than any other single item. This will be appreciated by those who have observed the functioning of apparently duplicate grit basin channels the influent ends of which are fed from a sewer coming in at even the slightest of angles. Then,

too, most of us have watched the short circuiting of settling tanks and have found it difficult to understand. It may be possible to better the operation of either a grit basin or settling tank by making slight adjustments of the baffles, yet how many times do we find the baffles made of concrete, or rigidly framed from structural steel? The same is often true of the weirs at the effluent end. To be effective they must be subject to adjustment and location change.

A grit basin and hand raked screens are simple pieces of apparatus but are seldom properly planned. An error frequently encountered is the omission of a drain to dewater one side for cleaning, or the inability to block off either channel at the effluent end. More often than not the screenings platform is too small for effective use and no provision is made to drain the screenings.

Concerning Sludge Digesters

The most serious objection to separate sludge digestion tanks (particularly at activated sludge plants) is the inability to handle the supernatent liquor during temporary upsets. If any units of the plant need to be in duplicate or to be liberally designed, digestion tanks should be. When a digestion tank goes bad, the correction most frequently and most effectively employed involves the axiom *"let it rest,"* but this is impossible with a single unit. On the other hand, liberal capacity will automatically prevent many upsets. If at all possible, provision should be made to send the supernatent liquor, at will, to the primary tanks, to the secondary tanks, to the sludge beds, or better still, to a lagoon in those situations where an open lagoon is both practicable and possible. Odor control and the usage of gas generated require that the digestion tanks be covered. In so doing, the utmost of caution must be observed to prevent the possibility of air getting back into the digester and, thereby, creating an explosive mixture.

There is not a great deal of published information relative to the details of digestion tanks, and much remains to be learned relative to the area and location most effective for heating coils, the position of supernatent liquor outlets, sludge withdrawal pipes, and of sludge inlet arrangements. Speaking only for myself, I find a great deal of worthwhile information on these subjects in the 1935 edition of Volume 3 of "American Sewerage Practice" by Metcalf and Eddy.

Effluent Return

Good influent and effluent arrangements are more necessary on the final settling tanks than on the primary tanks. If a primary tank operates badly, the settled sewage may still be handled successfully by the subsequent biological processes, but when the final tank goes bad, it results immediately in a bad final effluent. It is becoming good practice to provide means to return a substantial portion of the final effluent from trickling filters, to the primary tanks. This effects sewage dilution and a reaction somewhat comparable to the return of sludge in the activated sludge process, and is particularly recommended during dry weather for small plants handling the flow from combined sewerage systems and those receiving considerable industrial sewage. In fact two plants in Illinois have bettered their operation by making such provisions after they have been in operation for a time.

Although the pumping equipment is the heart of all plants, it is seldom possible to provide completely duplicate units. The comparatively recent development of the variable speed motor drive gives a partial but practical solution to the question of duplicate units.

Small plants should be equipped with laboratory facilities sufficient to make tests for B.O.D., dissolved oxygen, pH colormetrically, suspended solids, and residual chlorine if chlorine be used. It is true that in most instances, the operators of small plants do not make all these tests, but no other single feature attracts so much favorable comment as a clean and well kept laboratory. The equipment need not be elaborate but should be serviceable and should be housed in a neat cabinet providing a clear view of its contents. This is good psychology, and often is the compelling influence toward the retention of an operator of higher degree of intelligence than would otherwise be employed.

Too often we lose sight of, or fail to impress City Councils with, the fact that intelligent operation is just as essential as good design. We should all foster that idea before the plants are finished and convince the public once and for all time that the sewage treatment works operator shall be selected for merit and that later he shall be compelled to attend operators' schools and technical association meetings.

In Summary

Thus far I have striven to establish an alibi for the inadequacy of some of the smaller sewage treatment works, and in many instances engineers may properly and safely hide behind the alibi that there were insufficient funds with which to build the plant as they should have liked to do. Unfortunately we also hear occasionally that the engineering fees were so low that the designer could not afford to expend the proper amount of time on the preliminary investigations or on the actual design. This, I am afraid, is the real reason why some plants are poorly designed, but it is an indefensible alibi.

Who loses, when due to insufficient fees, the design is illy planned? First, the municipality loses, because it does not receive proper value for the money expended. Second, the designing engineer loses, because he fails to receive just and fair compensation. Third, all other engineers lose, because a precedent is established, a scale of fees fixed in the minds of adjacent municipalities. Fourth, the reputation of the designing engineer suffers in the end—and with it the standing of other engineers. "Let him who is not guilty cast the first stone."

Too often we engineers agree with a City Council to perform engineering services for certain low percentages. Unfortunately we are not bound by any agreements nor recognize any uniform scale of remuneration for doing various classes of work. On a three per cent design fee, one can make good money designing a storm sewerage project costing a quarter million dollars. On the other hand the conscientious engineer will lose money on a fee of eight per cent designing very small sewage treatment works. Yet one can point to several instances where engineers have asked only four per cent for designing and superivising the construction of small plants. Herein lies the reason why so many glaring errors and deficiencies appear. The economical design of a small tank requires as much, or more, study than does a large one, but we do not charge as much money. Why?

With all the above facts in mind, I lay much of the blame at the feet of engineers because of their failure to adopt and rigidly enforce a scale of remuneration commensurate with the magnitude and difficulties of the design. Until such a sliding scale is adhered to we shall continue to find the smaller plants designed incompetently. Also, I might add, until the municipal authority is made to see that the cheapest engineer is not the least costly.

Acknowledgement—The above article was presented as a paper before the Illinois Society of Engineers, Chicago, Ill., January 30, 1937.

C.S.W.A. HOLDS SPRING CONFERENCE AT STOCKTON

By A. M. RAWN
Associate Editor

CONVENING at Stockton, California, on April 23 and 24, 1937, members of the California Sewage Works Association met for their Ninth Annual Spring Conference. Of two hundred fifty members as of the date of the meeting, one hundred sixty-four members and guests registered; therewith, establishing two records —one in membership, the other in meeting attendance. After gathering for registration at the Hotel Clark in Stockton, members proceeded by automobile caravan to inspect the Lodi activated sludge plant and the North and South Stockton separate sludge digestion plants, now undergoing reconstruction.

At a luncheon meeting, held jointly with the Engineers Club of Stockton, after a word of welcome from Vice-Mayor Woodrow Coale, Edward Hyatt, California State Hydraulic Engineer, briefly reviewed the problems and progress in the development of California's vast Central Valley irrigation project. Friday afternoon was devoted to a technical session, concluding with an operators' symposium on mechanical equipment for sewage works. At the evening dinner the Association's Committee on Awards presented the city of San Bernardino with the handsome bronze plaque* awarded annually to the member operating staff of that plant (in California) which has shown the greatest improvement during the year and the best support by civic officials. The plaque was accepted by Bard Livingstone, superintendent of the San Bernardino Water and Sewage Department, on behalf of the city. Unlike most California cities, but becoming more prevalent elsewhere, the sewage disposal facilities in San Bernardino are under the management of the Water Department. Following presentation of the Award of Merit, Mr. Earl M. Kelly, State Director of Public Works, addressed the group on problems involved in State public works construction in California.

On Saturday morning members convened in a short business session given over largely to the discussion of current matters of legislation, voluntary registration of sewage plant operators, and the plant operators' school, followed by discussions of the influence of cannery wastes on sewage plant operation, and sewerage problems in the Pacific Northwest. The session was closed with an interesting account, by R. F. Brown of the Los Angeles City Engineer's staff, of experiences and observations during a trip of inspection through the Los Angeles outfall sewer.

*An award made possible through a donation for the purpose which was established by the Pacific Coast Office of Wallace and Tiernan Co. and in effect for several years past.

To San Bernardino the Award

Theirs Was the Plant Showing Greatest Improvement. Bill Berg, Supt. Treatment Works, and His "Boss," Bard Livingston, San Bernardino's Supt. of Water Works and Sewerage.

The Central Valley Project, by EDWARD HYATT, California State Hydraulic Engineer.

Mr. Hyatt stated in part that the Central Valley Project was a plan for utilizing the water resources of the Sacramento and San Joaquin Rivers to provide water for existing developments in the two river valleys and the upper San Francisco Bay regions. The project involved 3,000,000 acres of settled land and a population of 900,000. In addition to irrigation betterment navigation on the Sacramento River would be restored, and power to the amount of 1,500,000,000 K.W.H. was to be developed annually; costly intrusion of salt waters into the Sacramento River would be corrected and increased flood control protection would additionally benefit the area.

The speaker noted that investigations for this vast work have been under way since 1920 and in the interim there had already been lost to State and Nation an amount sufficient to complete the project—about $170,000,000. Upon completion of the work in about eight years, 50,000 acres of productive land today abandoned, plus 200,000 acres so seriously affected by water shortage as to be unprofitable, will be restored to the productive area of California. The importance of the project is realized when considering that 40 per cent of the state's area (66 per cent of its cultivated area), is to be relieved of the threat of ruin by water shortage, or salt water intrusion.

Stream Pollution of the Mokelumne River by Winery Wastes, by PAUL A. SHAW, Division of Fish and Game, State of California. Mr. Shaw directed attention to an investigation by State departments of conditions resulting from the discharge of wine slops into the Mokelumne River. A co-relation of production data with analyses of wastes indicated that the population equivalent pollution load from five tributary wineries was such that the river provides dilution varying from 1.5 to 3.2 cubic feet per second, per thousand population equivalent. In addition, six wineries are favorably

E. A. Reinke, Prin. Asst. Engr., Calif. Dept. of Health, President of C.S.W.A.

Ray Ribal, Sanitary Engr., Oakland Sewer District, Secy.-Treas., C.S.W.A.

located to discharge wastes into the river if so permitted.

The physical characteristics of the river were such that two critical areas of low dissolved oxygen content occur during the period of waste disposal, the most critical being located twenty-five to thirty-five miles below the major sources of pollution. In 1936 dissolved oxygen in this area was approximately 46 per cent or normal and, on the basis of the 1936 observations, are believed to have been less than 25 per cent of normal in 1935. The available rate of surface re-aeration had been calculated from the physical and chemical data, such value being approximately 110 pounds per acre per day at zero saturation, with re-absorption at higher saturations proportionately lower. Mr. Shaw stated that heavy growths of fungus, a dark appearance of the water and lowered pH also result from contamination by winery wastes.

To correct the disastrous effects on fish life, the Division of Fish and Game had issued an order prohibiting further discharge of still slops into the river and, in consequence, the California Wine Institute is providing assistance to its member wineries, seeking a satisfactory means of disposal.

Treatment of Effluents, by S. I. ZACK, Sanitary Engineer Filtration Equipment Corporation, New York City.

Mr. Zack prefaced his remarks with the statement that until about five years ago the methods of sewage treatment left a wide gap between primary and secondary processes; that the revival of chemical treatment and development of automatically cleaned magnetite filters had provided an effective process intermediate between the two. In addition, these straining units had supplied a means for correcting or improving effluents from secondary as well as primary processes of treatments.

In contrast with magnetite filters, which have been comprehensively tested and for which data are available from full-scale plants, Mr. Zack stated that there is little available information regarding sewage filtration through backwashed sand filters; that only modest experiments had been made here and abroad with the latter and these on such a scale as to render no conclusive evidence.

By means of charts and diagrams the author illustrated the futility of attempting to judge a treatment plant process, particularly with respect to the removal of suspended solids by merely indicating the percentage reduction which the process achieved. He pictured the fact that the higher the influent settleable solids (contrasted with suspended solids), the greater will be the percentage removal by any process; and, went on to say, that subsidence followed by filtration would produce a more uniform effluent—*i. e.*, one reflecting less of the varying characteristics of the influent and one suffering less from the vagaries of process, than any other intermediate process.

The author continued with a resumé of operating costs and data from operating plants and directed attention to the new type of downflow magnetite filters to be erected at Denver, Minneapolis and Cleveland. He stated that with a 0.5 m.m. grain size, rates of 2 to 4 gals. per sq. ft. per min. are workable, while at 0.85 millimeters grain size, rates of 2.5 to 6 may be filtered. In both instances, the rates applied only when filtration has been preceded by one hour or more of sedimentation.

Mr. Zack concluded by directing attention to five positive economies which the magnetite type of filter will effect: (1) Savings in chemicals to accomplish a definite treatment; (2) Reduced size of tanks to obtain uniform effluent; (3) Ability to "polish" preliminary or secondary effluents; (4) Prevention of secondary depositions of solids in diluting waters; (5) Improvement in the esthetic value of effluents.

Operators Symposium, Mechanical Plant Equipment—Nine plant operators contributed discussion and remarks. In general, the remarks were directed towards improvements and economies which had been effected in the plants during the past year or so. Some of the operators, however, took this occasion to present a frank discussion of the types of equipment which, obviously unsuited to sewage treatment works, are still from time to time being installed. Particular attention was directed to types of sewage pumps and to pump bearings. The operators agreed that vertical centrifugal pumps should be installed only where the horizontal type (close coupled), could not be placed; that impellers for sewage and sludge pumps should be of the hardest and most durable metal and that all sewage and sludge pump bearings should be of the split sleeve type and hard steel babbitt lined.

It also appeared to be the consensus of opinion that submerged sewage and sludge equipment, with moving parts, should be avoided whenever possible and that the most acceptable type was that which presented the fewest number of underwater parts. Some surprise was expressed by operators at the persistence with which engineers designed sewage treatment works with poor cleansing and drainage facilities; with multitudinous stairs and ladders to climb and with mechanical equipment bunched together, making for difficult maintenance. It was, in a measure, an operators' field day and while many of the indictments were humorously made, they were none the less barbed and, from the operators' view, very much to the point. All agreed that caravans and meetings of the Association afforded a splendid opportunity to see and hear of improvements as well as the mistakes made by others. The discussion closed with the suggestion that a little consultation between the designing engineer and an experienced plant operator might go far toward the smoothing out of unnecessary operation annoyances and reductions in cost of operation or maintenance.

"Brass Hats" and the Boys That Do the Work

(1) *Lodi's Fred Post (Supt. Treatment Works) and Clinton Henning (City Engr.)*; (2) *"Alex" Bell (C.S.W.A. Vice Pres. and California's Pioneering Chlorinator Peddler, and Expert Ink-Well Dodger, in Those Early Days for "W & T")*; (3) *Lysle Peyton and Fred West (Twin Operators of Palo Alto's Sewage Treatment—Cannery Waste Disposal Plant).*

Carl R. Green, State Sanitary Engr. of Oregon; Prof. Leon B. Reynolds, Leland Stanford Univ. (Charter President of C.S.W.A.); Paul R. Shaw, Engr. California Fish and Game Commission.

Cannery Wastes at Palo Alto, by J. H. KIMBALL and T. R. GREGORY, Plant Operators, Palo Alto, Calif.

Although the population of Palo Alto was but approximately 20,000 (1.6 m.g.d. average flow) the authors revealed that with the local cannery in full operation, the population equivalent of sewage inflow reached a peak of 57,000 per day at the Palo Alto primary treatment (separate digestion) plant. By careful laboratory analyses they had determined the following average population equivalents for the canning plant when operating on different packs: Spinach (21,000); Tomatoes (35,000); Peaches (37,000); Apricots (6,000).

During the canning season of 1935 cannery wastes reached the plant uncomminuted and floated on the subsidence tank to a depth of 2.5 feet, at such thickness the automatic skimmers failed to function and the tanks were skimmed by hand. The situation being explained to the cannery, a comminuting machine had been installed in 1935 and the condition with respect to floating solids greatly alleviated.

In a chart of analyses for two seasons' operation, the excessive rise in B.O.D. values in the effluent from the primary sedimentation tank was clearly illustrated; and this observation brought forth a general discussion of the probable effects of disposing of ground garbage in sewers. This in respect to added stream pollution or the over loading of secondary processes and expense of plant extension and power use. It would appear, from Palo Alto data, that ground garbage will raise the B.O.D. of primary effluents more than the unground, but that grinding greatly facilitates subsidence.

Sewage Disposal in the Pacific Northwest, by CARL E. GREEN, State Sanitary Engineer, Portland, Ore.

Mr. Green, past president of the Northwest Sewage Works Association, told of the efforts toward pollution abatement which were being made in Washington, Oregon and Idaho, stating that until recently nearly all sewage disposal in these areas has been by means of dilution in inland rivers or in lakes or salt water; that today in the three states, there are but three cities employing complete treatment. Treatment works at Yakama, Wash., now nearing completion, would make the fourth.

In describing the Yakama works the speaker directed attention to an unusual condition of flow, stating that during the three months: December, January and February, when irrigation water was not being used, the daily average flow in the sewers amount to 4 m.g.d. During the irrigating season this flow increased to 18 m.g.d., due to the raised ground water level and leaking sewers.

Mr. Green briefly discussed sewerage facilities in Seattle, Tacoma, Portland and Boise where, at present, disposal is by direct discharge of raw sewage in neighboring lakes or rivers or in the case of Seattle and Tacoma, into Puget Sound. He commented on the heavy increase in flows during the cannery seasons; the burdens imposed upon the Columbia River and its tributaries, by sulphite wastes from paper mills. More recently state health authorities, acting in conjunction with fish and game commissions and the Isaac Walton League, had been bending every effort in an attempt to preserve the purity of the Northwest streams for recreational purposes.

"Inspection of the Outfall Sewer of Los Angeles City," by R. F. BROWN, Assistant Maintenance Engineer, Sewer Department, Los Angeles.

In a talk, profusely illustrated with lantern slides, Mr. Brown described his trip of inspection through some ten miles of the 12-foot diameter Los Angeles City outfall sewer leading to the disposal works at Hyperion. The speaker, equipped with oxygen helmet, flood lights, camera and a short-wave radio sending set, floated in a small boat from manhole to manhole inspecting the sewer's interior tile lining and photographing representative views. From overhead his location in the sewer was noted by a party following along on the ground surface and Brown talked directly to them *via radio,** describing conditions as his boat progressed—the ground party noting the stations.

The inspection was made with the sewer in operation to avoid bypassing into an adjacent drainage canal and discharging raw sewage directly upon pleasure beaches. Sewage in the line is septic and the air so deficient in oxygen as to make such a trip hazardous in the extreme.

Brown noted and photographed many locations where oxidized H_2S had attacked the concrete sewer's interior, spalling off the vitrified clay liner blocks installed as a protective measure, and penetrating the concrete for a number of inches. Such places were identified for future repair. The trip of inspection caught the popular imagination, and Brown's ride to fame through a sewer, has resulted in his being commissioned "Admiral of the Los Angeles Sewer Navy."

[*We would hazard a guess that this represents the very newest and most novel of the many uses of radio transmission. —Ed.]

At Stockton's Reconstructed Plant

(1) *Lyle Peyton, City Engineer, and Fred West, Supt. Treatment Works, Both of Stockton;* (2) *J. H. Van Norman, Chief Operator, Los Angeles City Disposal Plant (Hyperion), and C. F. Tenent, Chief Operator, Los Angeles County Treatment Works (Harbor City);* (3) *Sam I. Zack, of Filtration Equipment Corp. (A Long Way from Home), and Prof. Charlie Hyde, of California University (Needs No Introduction to Readers of* WATER WORKS AND SEWERAGE).

ILLINOIS SECTION SEES AN ADVENTURE IN WATER WORKS PLANNING

By H. E. HUDSON, Jr.*
Chicago, Illinois.

LED by that pioneer, Chairman Charles H. Spaulding, the members of the Illinois Section, American Water Works Association, attended a two-day session on April 29th and 30th at Springfield, Illinois. Highlight of the meeting was the inspection of the Springfield Water Departments' new Lake Springfield and new filtration plant. On this trip, during which a buffet luncheon was served at the beautiful beach house on Lake Springfield, the members heard a comprehensive paper by S. T. Anderson, Springfield Water Works Superintendant, on the development of the Lake Springfield project, and saw the recently completed water treatment plant. This plant, a softening plant, features brief pre-treatment with lime and a coagulant, followed by filtration at high rates through very coarse sand. Though recarbonation is not used, carbonate stability is automatically achieved.

The technical sessions were held at the Abraham Lincoln Hotel and the attendance was large at all sessions. At the banquet on the evening of the 29th, entertainment was furnished by the City Water, Power and Light Chorus of Springfield, and by Genial George Prindle who spoke on something or other. National Secretary Harry Jordan, stressed the value of the A.W.W.A. to members and the value of strong sections to the A.W.W.A.

Chairman-elect is Frank C. Amsbary of Champaign, and Ray Crozier, Peoria, was elected Vice-chairman, with W. D. Gerber of Urbana repeating as Secretary-Treasurer. The Section plans to sponsor operators' conferences as a means of organizing the Illinois water works men and giving them valuable in-service training. Though no definite action was taken on licensing, the general opinion seemed to favor voluntary certification for the time being.

DR. MAX SUTER, Illinois State Water Survey, described an accurate method for hardness determination, using titration of the neutralized sample with potassium palmitate in the presence of an indicator. L. A. NALESFSKI told of some of his work on the test at Decatur.

According to JAMES G. WEART (State Department of Public Health), in his paper describing results of a recent Flouride survey, there are 330,000 people in Illinois receiving water containing at least 0.9 p.p.m. of Fluoride.

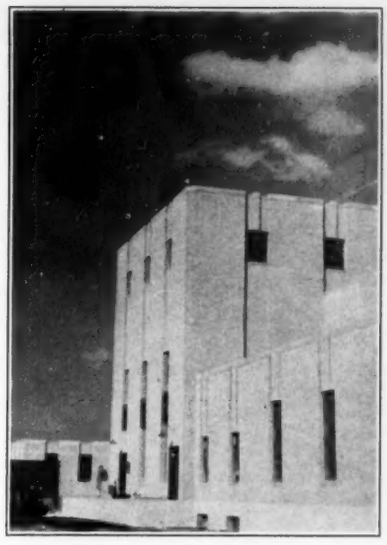
JOHN R. BAYLIS, Chicago Experimental Filtration Plant, decried the failure of present-day washing procedures to keep the filter beds in condition good enough to produce satisfactory water, and told of a number of recent experiments on filtering media and washing media. ROY GRAVES of Springfield told of glass tube filter experiments and their results.

W. H. LOVEJOY (Louisville, Ky.), outlined the remarkable efforts of the Louisville Water Company to maintain water service through flood difficulties. An amusing feature of his talk was the statement that a most valuable auxiliary proved to be a baptismal suit borrowed from a nearby church. And, C. M. ROOS (Cairo), told how it feels to spend two weeks in a flood-surrounded town with water lapping at the top of the levees and sand boils erupting underfoot. He gave a general resumé of the effects of the flood on Southern Illinois. Some interesting water works engineering stunts were described by H. A. SPAFFORD (Ill. Dept. of Public Health). Some of these were: the operation of a well pump with tractor power, a chemical feeder with a washing machine motor, and a mixing basin operated with an outboard motor.

PROF. SEICHI KONZO described some interesting experiments on a full-sized house at the University of Illinois. It was found by these tests that air-conditioning methods using small quantities of water were as cheap as methods requiring large supplies of water.

E. N. BOWLES, Westinghouse Electric and Mfg. Co., gave a general description of air-conditioning equipment. And how air-conditioning is affecting the water supply and sewerage system of Chicago's central district was told by L. D. GAYTON, Chicago's City Engineer. The water supply is adequate, but the sewers are taxed to capacity by the air-conditioning load. Mr. Gayton gave some useful unit figures for calculating the effect of air-conditioning on water and sewer uses. (More of this at the A.W.W.A. Convention.—Ed.)

W. D. GERBER, State Water Survey, presented a paper on the availability of ground waters for air-conditioning, telling of the temperatures and quantities of water to be found in various parts of Illinois.



Springfield's New Softening-Filtration Plant

*Junior Sanitary Engr., Dept. of Public Works, Chicago, Ill.

Columbus Dedicates the Gregory Library

The professional library of the late John H. Gregory, Professor of Sanitary Engineering at Johns Hopkins University and for 22 years consultant to the City of Columbus, Ohio, was formally accepted and dedicated by Columbus officials on May 7th, with appropriate ceremonies. Officially the new library becomes known as "The John H. Gregory Sanitary and Municipal Engineering Reference Library." It was presented at Professor Gregory's especial request as an expression of appreservice with the City. The committee in charge of the dedication was headed by Clarence B. Hoover, Director of Utilities.

PENNSYLVANIA OPERATORS MEET WITH FOUR STATES SECTION

IN Philadelphia on April 22nd and 23rd the Four States Section of A.W.W.A. and the Pennsylvania Water Operators Association met jointly.

The forenoon of the first day was devoted to presentation of papers followed by an afternoon tour of Franklin Institute. That evening, followed the dinner and dance with good entertainment and an outstanding talk on "What A.W.W.A. Means to An Operator" by H. E. Jordan, Executive Secretary of A.W.W.A.

Harry M. Freeburn

The forenoon of the second day was devoted to a classroom method of discussing and analysing "Operating Problems"—the "professor" being a real one, in the person of Professor Lewis Carpenter—borrowed from New York University for the day.

Business Meeting

(Chairman Ezra B. Whitman, Presiding)

The following resolution was presented, discussed and passed by the Four States Section:

A Resolution Condemning the Appointment of Local Agents for Consulting Engineers and Water Works Materials

Whereas during the past few years open price agreements have brought about uniform prices on a number of water works materials and whereas there has resulted a tendency on the part of manufacturers to substitute favoritism for competition by the appointment of local agents who are unfamiliar with the water works requirements of such materials and perform no service in delivery.

Whereas there is a growing tendency for local agents to influence the appointment of consulting engineers and the fees to which they are entitled for their services.

Whereas this practice tends to embarass the purchaser in his selection and increase the cost of the materials to the utilities and in the end to the ultimate consumer;

Therefore Be It Resolved by the membership of the Four States Section, American Water Works Association that the practice of appointing such local agents be condemned and that every effort be used to discourage and eliminate it as soon as possible.

Officers for Ensuing Year

Officers named for the ensuing year are:

Chairman, Harry M. Freeburn, Philadelphia, Pa.

Vice-Chairman, Carl J. Lauter, Washington, D. C.

Sec'y-Treas., Carl A. Hechmer, Hyattsville, Md.

A.W.W.A. Director, Chas. H. Becker, Philadelphia, Pa.

Trustees, I. M. Glace, Geo. R. Taylor, Abel Wolman, Edw. S. Hopkins, Ezra B. Whitman (Immediate Past Chairman).

A Discussion of Operating Problems

Professor Lewis V. Carpenter, employed the best wiles of his profession in developing, discussion, questions, answers and arguments while conducting a "school" on "Operating Problems."

(1) The Relationship of Air Conditioning to Water Supply was opened by L. L. LEWIS, Chief Engineer of the Carrier Corporation, who briefly reviewed previously published data by him pertaining to water consumption as influenced by modern air conditioning (see WATER WORKS AND SEWERAGE, February, 1936, p. 61; September, 1936, p. 335). During 1936, he said, 125 million dollars worth of air conditioning equipment had been installed in the United States, with Washington, D. C., taking first place in having reached 40.5 per cent of the predicted saturation limit in installations. In the Four States Section area Philadelphia had been second and Baltimore third. Because of the fact that the commercial and industrial installations conserved water by recirculation developments to the present had not put a noticeable load on water plants. In the future extension of air cooling to residences, where water was not recovered, there was more of concern for the water utility management. Such load expected during the 2 to 3 months when demands were already great, was something to be thinking about.

CARL J. LAUTER, Superintendent Filtration, Washington, D. C., said that they had not been able to ascribe more than a 5 per cent increase in water demand to air conditioning in 1936. Mr. Lewis, however, said that circumstances in Washington rendered the 5 per cent increase misleading as a true index of water usage in conjunction with the rapid growth of large air conditioning installations there. Mr. Carpenter cited cases wherein sanitary sewers and treatment works had been overloaded due to air conditioning installations (notably from private supply) which wasted practically all of the water.

(2) "Bacterial Pick-up in Distribution Systems." Mr. Lauter, being asked for his exprience, said that in winter no trouble had been experienced but in summer the pick-up of bacteria had been noticeable. Since using the ammonia-chlorine treatment the trouble had been much less pronounced. Comparison between the tap water from the two plants had especially indicated the efficacy of residual chlorine carried out to the reaches of the system. Mr. Lauter said that in chlorinated samples residual was destroyed with thiosulphate at the time of sampling, if samples were to be held before starting the bacteriological work. The practice made a difference.

L. H. ENSLOW, asked for his experiences, said that Mr. Lauter's diagnosis seemed the proper answer. Bacterial multiplication in the coating on the walls and deposits in mains being subdued in winter (low temperature water) came into action when the water became warmer. The same phenomena caused corrosion on dead ends and bad tastes or odors. By ordinary chlorination the trouble spots were not reached without too excessive chlorine dosage at the plant, whereas the persistency of chloramines made it possible to reach the ends with a residual and minimum taste. In the pipe slime organisms flour-

ished and even the coli-aerogenese group seemed to multiply there. While having no real health significance the records looked bad and unfortunately there was no way of proving the unimportance of the slime picked up organism from those coming into the treatment plant. In the end, it was far preferable to eliminate the pick-up; thus, have nothing to explain away in the records, and sleep more soundly at night.

MR. BRUSH, said that he had for many years had coli-aerogenes in the New York system but hadn't lost any sleep over the fact, since the laboratory had assured him that they were only attenuated forms of coli.

A member advanced the interesting theory that bacterial pick-up was due to the fact that deficient chlorination merely stunned some resistant forms which later revived out in the system.

E. F. DONALDSON, Superintendent of Purification, Annapolis, Md., reported that since using ammonia-chlorine treatment (1:5 ratio), there had been an increased bacterial pick-up and with it dirty water on the dead ends. (It later developed that the Annapolis mains, used for many years prior to filtration to remove iron, manganese and organic matter, were probably badly coated. The ammonia-chlorine treatment had been causing the slime to slough off and disintegrate. From the slime had come the bacterial pick-up in the absence of sufficient residual chlorine. It seemed to be time to do some serious main flushing rather than unloading manganese organic coatings through services. Now started, it is probable that the sloughing will continue even if the ammonia treatment be stopped.—Ed.)

F. E. STUART, President, Activated Alum Corporation, Baltimore, Md., remarked on the relationship between taste occurrences on dead ends, heavy draughts or flushing, and bacterial pick-up. He believed that studies of 20 degree counts would reveal the reason for oxygen depletion, tastes and corrosion. There seemed, likewise, to be a relationship between chlorine demands and dead-end troubles, including aftergrowths. In this consideration, the complete satisfaction of chlorine demand in pre-treatment yielded filter effluents with chlorine demand practically satisfied.

WM. C. EMIGH, City Enginer, Coatesville, Pa., referred to troubles, seasonably, in destroying 48 hour gas formers which seemed to be of a resistant spore forming type. They seemed to possess no sanitary significance.

L. H. ENSLOW then told of a case of bacterial pick-up which had given him as an operator (not to mention the city health laboratory) much concern. The trouble was finally traced to decaying wood in an elevated tank. He had often thought, since, how relieving it would have been in 1915 to have had ammonia-chlorine treatment and residual chlorine to "pickle" that piece of trouble making wood.

(3) "Losses in Distribution Systems."—S. F. NEWKIRK, Superintendent Water Department, Elizabeth, N. J., the first "victim" called to an accounting by the Chair, said that they had been collecting for 82 to 92 per cent (87 per cent average) of the water entering the distribution system and therefore had felt fairly content that leakage surveys would not pay their way. However, he had found that an occasional jacking up of meter readers resulted in the finding of more leaks even though most were on the consumers side of the meter. They made a practice also of checking up minimum night rates of flow through the master-meter. If the flow seemed to run higher than the normal (30 per cent of the average flow for Elizabeth) then search for main leakage and water stealing was instituted.

J. H. STROHMEYER, Assistant Water Engineer, Baltimore, Md., pointed to the variations in accounted for water which had been recorded for various distribution zones in Baltimore. Depending upon the class and size of consumers in the zone, the figures had varied between 70 and 90 per cent. On the whole, they had found an 86 per cent accounting about the best average attainable.

HARRY HALL, Chief, Washington Suburban Sanitation District, reported 80 per cent to be their average and explained that with scattered District systems, free water to public buildings and volunteer fire department drills they were not apologetic over the 80 per cent. A very similar experience was recited by Carl H. Boas, Mgr. Mt. Penn Suburban Water Co., Reading, Pa., serving 9 communities, also having volunteer fire units required to keep records of minutes of hydrants in service.

HOMER BECKWITH, Engineer, Pitometer Company, Harrisburg, Pa., cited examples to show how difficult it was to compare tightness of systems on the accounted for water basis. Where two nearby towns were compared, in one case the average consumption was 15 gals. per capita and checked survey could account for not more than 75 per cent—the figure being 45 per cent before corrections. In the other, with about 60 gals. per capita, 90 per cent could be accounted for after all possible corrections. In another community the marked effect of one large consumer was shown by the water utility being able to show collections for 90 per cent of the water pumped. On checking up, only 60 per cent of that going to the smaller consumers could be accounted for. It was not unknown, therefore, that a Pitometer survey actually yielded a true water accounted for figure lower than the water utility records indicated.

(4) "Causes of pH Drop in Distribution Systems"—Through questions and answers at random from the floor, the Professor developed the fact that pH drop could be due to:

1.—Calcium Carbonate deposited on the pipe walls.

2.—Organic Matter decomposition.

3.—Bacteria.

4.—Temperature.

5.—Increased CO_2 content.

In short, 2, 3, 4, 5, were inter-related and 4 was the important element in contributing 5 as the result of 3 acting to produce 2. From this came the by-product 5 to cause a pH drop and corrosion.

Lack of space precludes coverage of the following papers which were presented:

"Operation of Reading's Filtration Plant," by Walter Strockbine, Chemist, Bureau of Water, Reading, Pa.

"Every Filter Plant Its Own Research Laboratory," by George D. Norcom, Cons. Sanitary Engr., Red Bank, N. J.

"Problem of Back Syphonage," by E. L. Penfrase, Copper and Brass Research Ass'n, New York City (aided by educational moving picture).

"Activated Carbon, Its Adaptation and Points of Application," by F. A. Sigworth, Industrial Chemical Sales Div., West Va. Pulp and Paper Co., New York City. (A report and analysis of questionnaired returns from 137 plants, 71 of which use carbon continuously.)

A FEW KINKS

By D. R. TAYLOR

Superintendent
Roanoke Water Works Co.
Roanoke, Va.

The Author

THE following are a few "short cuts" for correcting or alleviating pestiferous situations that occur occasionally in the maintenance and operation of water works systems. The following methods have been either learned by experience or handed down from employees or other water works men of greater experience. Most of them are so simple that while most of the older superintendents are familiar with them, the writer feels that there may be some younger superintendents who are just beginning their life's vocation in the water works field to learn something from these suggestions. If so, he will be well repaid for his efforts in preparing this article for publication in Water Works and Sewerage.

Sticking and Non-Closing Valves

All of us have had the experience of closing a valve in the distribution system and finding that it was leaking. Often times such a leaking valve has not been entirely closed, due to the formation of rust or incrustation which has formed inside of the valve, and especially between the gate rings. The rust that has formed at the bottom of the valve between the rings plus that rust that falls to the bottom when the valve operates is often sufficient to prevent the gates from closing sufficiently to cut off the water entirely. It is often possible to break off this rust and dislodge it by closing and opening the valve ¼th way several times. Closing the valve breaks up the rust and partially opening the valve creates a flow of water at a sufficiently high velocity to wash the accumulation of broken rust from between the gates rings at the bottom of the valve.

Nature's Valve Box and Leak Locator

Did you ever take advantage of a light snow to locate covered up valve boxes or leaks? There are certain seasons of the year when a light snow, provided it covers the earth well, serves to lead the searcher to both. The warmth or heat from the earth will accumulate in the valve boxes, especially those that are vaulted and covered with manhole covers. We find that this heat will tend to melt the snow on top of the valve boxes or valve vaults, enabling one to easily locate such valves, even though covered with dirt, or asphalt and not discernible before the snow falls.

In a similar manner leaks may be located in the cases where the water which is wasting does not come to the surface but finds some underground outlet. The water being warmer than the earth or street surface tends to melt the snow directly above the leak. These cases are of course rarer than those of the valve boxes but there are times when such observation saves many dollars in the matter of locating leaks. Of course, the safest and most dependable method of locating such leaks is with the use of equipment specially made for the purpose. These, however, could better be described in a story pertaining to—"The Use of Special Water Works Equipment."

Pipe Pushing, Aided by Water Jet

Quite often it is more convenient, practicable or cheaper to push pipe, either for services or small mains, under the pavement than it is to cut the pavement. Where galvanized pipe is used and the soil in question is sand, loam or clay the job is not difficult, however where the clay is exceedingly compact and hard the job may be facilitated by the introduction of a stream of water under pressure. The water may be introduced at the rear end of the pipe being pushed and allowed to escape from the front end through a reducing coupling thereby softening the earth that is being penetrated.

Many water works systems have discontinued the use of iron pipe for services and have adopted copper service pipe exclusively. Where it is desired to install copper service across the street or road, without cutting the pavement, the matter of pushing presents temporarily some difficulty. This difficulty may be easily eliminated by pushing 1¼ or 1½ inch iron pipe under the pavement and then pushing the copper service pipe through this iron pipe. Second-hand iron pipe or iron pipe that has been junked may be used for this purpose.

In this connection a method for replacing old services with copper tubing was described in the 1935 Edition of WATER WORKS AND SEWERAGE REFERENCE AND DATA BOOK. In this case the pipe pusher is used as a "pipe puller." The tubing is connected to the old service pipe and pulled through as the old pipe is removed by the puller in a pit. One town we know of uses a truck and chain for pulling through the old pipe with the new attached.

Locating Stub-Services

Most electric pipe locators require two positive connections. In the case of locating stub services the two positive connections are impossible; however there is a plan by which the stub service can be located fairly successfully. One may drive a steel bar into the ground approximately at the point where it is thought the service terminates, at the curb or in the consumer's property. Then the connection is made to another service or fire hydrant and to the iron bar driven into the ground. The signal strength in such cases is not quite as strong but many stub services have been located in this manner although it may be necessary to move the iron bar frequently until it is driven close enough to the end of the stub service to get the signal, but with the proper perseverance and patience it is usually possible to effect a great savings in the locating of stub services in this manner.

Locating Consumers' Leaks

All water works officials are called upon to investigate the cause of high bills. Two short cuts for locating leaks in the consumers' plumbing may be new to some readers.

Where a leak is clearly heard, either with instruments or the naked ear, although no leak is visible, it is often possible that the leak may be in one of the modern type flush valves. Oftentimes by sprinkling a small quantity of talcum powder on the surface of the water in the flush tank or the commode a movement of the water is immediately noticed. It is a positive means of proving and spotting the leak.

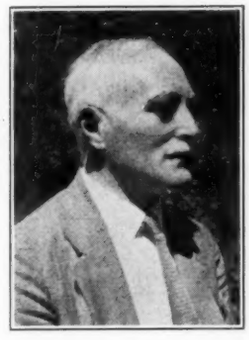
When the leak is so small that registration on the meter is not immediately discernible it is often possible to detect movement of the meter by removing the register and laying a match on the stuffing box spindle gear. This gear moves so much more rapidly than the hand of the register that it is relatively easy to detect movement of the meter.

A BRITISH SEWAGE WORKS ASSOCIATION MEETING*

Impressions of a Guest from America

By DR. WILLEM RUDOLFS[1]

Rutgers University
New Brunswick, N. J.



Dr. W. Rudolfs

FIRST impressions are frequently lasting. Especially when received in new, different or unusual surroundings. Many of us attend water and sewage operators meetings voluntarily for information, others for business and still others are sent by their employers. Sometimes these meetings are not very stirring, impressive or worth while, although attendance may be exhilarating to some. Other meetings stimulate, promote good fellowship, create interest and give new viewpoints to old problems, help the individual in solving his specific problem and bring information which otherwise could not be obtained. Naturally, the place of meeting and the type of attendance has a good deal to do with the success of the gathering. The reading of papers alone does not make a meeting successful, even if the papers are properly prepared and well presented. Some times one has the feeling that something is lacking without being able to say what is missing or what is at fault.

A Meeting Worth Mentioning

The annual summer meeting of the English Institute of Sewage Purification (association of Managers of Sewage Disposal Works) held at Exeter was, judging from the program, not much different in routine from similar meetings held in this country. The two and one-half day conference consisted of reading of papers, visits and luncheons.

Place

The meeting place was a beautiful old Guild Hall. Dais, hardwood benches, choir, stained glass windows set in lead, and walls covered with portraits of notables of bygone days, made the setting for the discussions. It is not to be inferred that the English always have beautifully preserved 16th century buildings available for sewage meetings. But, to the visitor, it appeared that the surroundings were quite important in connection with the success of the Exeter meeting and the receptability of the audience. There were no noisy distractions from a nearby dining room or kitchen, no running in and out of persons, with the accompanying slamming or creaking of doors, or other disturbances. No whispered conversations in the audience or talking around the entrance to the room; no street cars or noisy trucks passing the windows.

Attendance

Looking over the audience and listening to the discussions an impression was gained that the attendance was not homogeneous as far as technical interest was concerned. In discussion with members of the Institute this was readily verified. Curiosity regarding the type of persons present led to the questions: What is their interest and how do you get them here? There were probably between 200 and 250 in attendance; registration having been completed by mail some time previous to the meeting. Preliminary notices had been sent out about three months before and a complete program about three weeks ahead of the meeting.

The great majority present were sewage works managers and assistants, members of sewerage commissions, municipal officials, with a sprinkling of representatives of industrial concerns and equipment manufacturers. For years English sewage works managers have seen the need of bringing their commissioners to the meetings. The Ministry of Health has sponsored this movement, so that in the preliminary announcement and at the front page of the invitation to attend, and again on the printed program the statement is made that "The Minister of Health has intimated that he sanctions, in the case of any Sanitary Authority whose accounts are subject to District Audit, the payment of the reasonable expenses which may be incurred in connection with the attendance at the Conference of two delegates, one of whom should be the Manager of the Sewage Disposal Works. Individual application to the Minister for sanction in respect of the Conference will not be necessary, so long as the proposed expenditure is within the limits indicated."

The result is now that frequently commissioners see to it that the sewage operator makes proper application for attending the meetings. A number of these commissioners go year after year and become quite conversant with the problems discussed—certainly a healthful and desirable attainment. Several commissioners expressed their opinion, privately to the writer, that the meetings were very helpful in their office, led them to read more about technical questions and allowed them to support intelligently the operator when changes or additions were needed. I found on several occasions that the commissioners were particularly keen that their operator should present a paper or take part in the discussion. Incidentally, these commissioners will take part in the discussion themselves and bring to the meeting the aspects of the official, especially when cost of operation and construction are concerned. This in turn gives the conference a somewhat wider scope.

Time

The program stated that members and guests would assemble at 9:45 a. m. at the Guild Hall and the meeting

* Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J. Division Water & Sewage Research. (Prepared upon invitation of WATER WORKS AND SEWERAGE.)
[1] Chief, Division Water & Sewage Research.

would be opened at 10:00 a. m. Wishing to see some people before the meeting, and basing my judgment upon experience at most meetings in this country, I believed that at least half an hour would be available when arriving shortly before ten. Talking to the Chairman, I noticed him watching the clock and when the Hall clock had struck the hour specified, the gavel come down; the meeting was open on the hour.

Papers

For a two and one-half hour session two papers were scheduled to be presented. The first day The Right Worshipful Mayor of Exeter welcomed the delegates briefly and opened the conference. (Note, that he did not keep the meeting waiting, sent no substitute.) It used to be customary in some of the technical American sanitary engineering sections to have the paper to be presented printed beforehand and distributed at the meeting. In England the papers had been printed and sent to the members some time in advance. The paper was therefore not read at the meeting. Instead at was "introduced" by the author, who added informal remarks about the work and presented additional information, where desired. This lasted some 15 minutes, leaving a full hour for discussion of each paper. The first discussor, moving the customary vote of thanks, had studied the paper. He then began telling how good the paper was, and followed with a thorough discussion, involving prevously thought-out criticisms of the material presented. The member seconding the vote of thanks did likewise and this was followed by discussions from the floor, leaving about 10 minutes for the author to answer. Naturally, the discussion (not to mention the criticisms) was lively and extremely interesting, allowing a thorough and fair evaluation of the paper presented, as well as bringing out side-lines and experiences of those present. Four papers were presented during the two morning sessions, leaving the remainder of the time for visits, inspections and sight seeing.

"Attractions"

After adjournment of the morning session the members departed to a nearby hotel for luncheon. The first day's luncheon was "by kind invitation of The Right Worshipful the Mayor of Exeter," attended by a number of city officials, and marked by a brief address of the Mayor. The second day luncheon was again an interesting affair, attended by local government officials. Here the president of the Institute delivered his annual address; the city engineer said a few words about his plant to be visited the next day and an alderman wished the gathering godspeed. There is nothing new in luncheon or dinner meetings, their success depends entirely upon arrangement and management. Attending a well organized luncheon or dinner meeting is a pleasure; a slipshod affair is a bore.

Visits to plants and structures have become an integral part of many regional water and sewage works meetings. Trips to industries are frequently included, excursion trips are less usual. A trip in buses along country roads with a definite aim (country place, park, natural monument) where refreshments are served is enjoyable, brings people in closer contact, gives chance to discuss mutual problems or experiences, leaves a pleasant impression of the conference and is inducive to attendance at future meetings. Leaving Exeter with a group of buses to visit and have tea (not cocktails) at a restored castle with beautiful gardens, and from there lumbering on over the moors to the well known Dartmoor prison, will certainly be remembered by the writer as an outing calling for repetition. The "Tea," consisting of thin slices of bread, cake, cookies, tea, and other accessories was an agreeable break in the trip.

English vs. American Meetings

The outstanding impressions comparing the English meetings with those attended in this country are:

1. Our programs are too hastily got up, are overcrowded. Papers are run through the mill of "mass production." Discussion is often not thought out and frequently is insignificant.
2. Sessions too frequently do not start on time, making programs more crowded, losing available discussion time.
3. Interruptions and noise, could often be reduced.
4. Luncheons, dinners, receptions, excursions could frequently be improved and made more attractive.
5. An organized drive for attendance of municipal officials, commissioners and other "outside" interests, would promote better meetings, build up active membership and participation, make for a better understanding between administrative and operating personnel and the problems of the latter group.

(6) In America too little encouragement is given by municipal officials to meeting attendance by managers and operators—less instructions to attend with expenses allowed.

In many respects American Associations should benefit by drawing a pattern from British experiences, and attempt what the English have accomplished.

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Unique Building For National Aluminate

One of the most unusual buildings ever planned is under construction in Chicago as the home of National Aluminate Corporation. It is to house the offices and laboratories of National's Research Division.

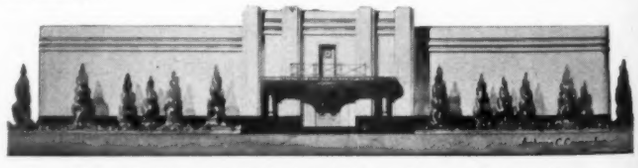
The building has been made windowless in order that it can be efficiently supplied with constant and scientifically predetermined illumination, and perfect weather conditions.

As to exterior beauty, the construction is of white matt-finished Terra Cotta with horizontal bands of strong blue at the top and panels of blue at the entrance. The feature at the extrance is the canopy and grill work of anodized aluminum—symbolical of National Aluminate's chief products.

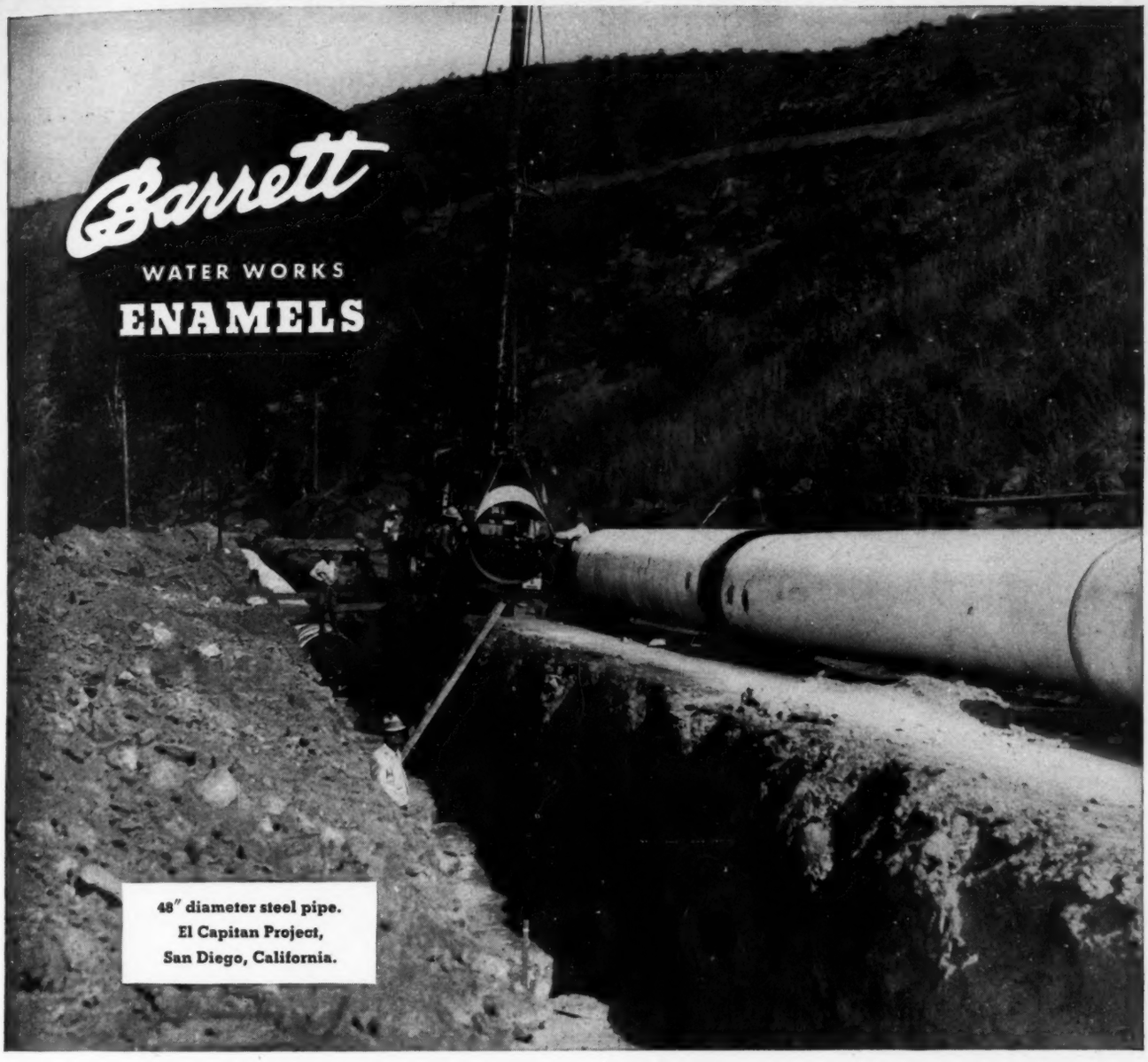
All rooms will have acoustical ceiling treatment, rubber tile floor covering and walls covered with wall-linoleum. Instruments in each room will reveal the climatic condition, which is subject to regulation to meet requirements or the wishes of the individuals using the room.

The interior feature is the grouped laboratory arrangement and the "boiler-room," containing 4 miniature boilers, which duplicate the designs of modern high-pressure equipment. These will be continuously in operation for demonstration and experimental studies.

Architects on this building are Ambrose C. Cramer, Inc., of Chicago. Air conditioning by Robert E. Hattis, Cons. Engr., Chicago, associated with the architects.



New Building of National Aluminate Corporation



Smooth, Mirror-like Linings Mean Increased Coefficient of Flow

Barrett Water Works Enamels are produced from a specially processed coal-tar pitch, the most stable bituminous material known.

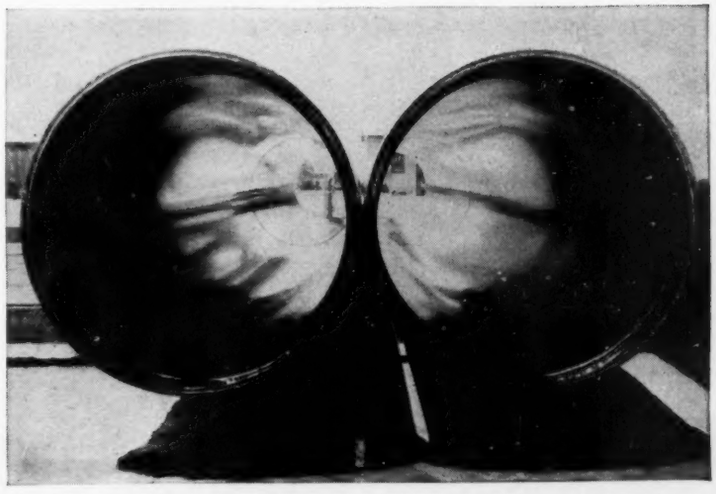
When spun in pipe, these enamels form a uniformly smooth, mirror-like lining that prevents corrosion and tuberculation, and maintains original line capacity.

Applied to pipe exteriors, these enamels provide a protective coating that is tough, highly adhesive, and strongly resistant to moisture absorption, soil acids, alkalis, etc.

FIELD SERVICE The Barrett Company maintains a Pipe Line Service Department to assist engineers in all coating problems, and also has available Field Service men whose assistance is offered where Barrett's protective coatings are used. Inquiries are invited.

THE BARRETT COMPANY

40 Rector Street New York, N. Y.



MANUFACTURE OF ACTIVATED ALUM GETS UNDER WAY

New Plant to Produce a Variety of Coagulants and Chemicals for Water and Sewage Treatment

The new plant of Activated Alum Corporation, located in the Curtis Bay Industrial Zone of Baltimore, Md., has recently gone into production. The company's principal product is activated sulphate of alumina, marketed under the registered brand name of "Black Alum," commonly referred to by users as "Activated Alum." Its distinctive black color (hence its name) is derived from the activated carbon which it carries as a coagulant-aid, and which (in the floc) serves likewise to stabilize sludge in coagulation basins and produce an improved tasting and more brilliant filtered water, containing a minimum of the trouble giving residual organic matter.

Activated Alum—"At Home and Abroad." In the Center Is the New Plant at Curtis Bay, Md. Below Is the Plant Office, Works Laboratory and Home-Berth of the Traveling Laboratory—Seen "Abroad" in the Upper Picture.

Another unique products developed by the company is "Coag"—this being a ferric-aluminum sulphate, with characteristics of both ferric sulphate and filter alum, and coagulating abilities under a wide range of conditions. Especially is "Coag" recommended for difficult waters, and for the chemical precipitation of sewages and industrial wastes.

A third product—"Filterseed"—is a specially prepared activated carbon for economical carbon applications to rapid sand filters direct—its featured quality being that it does not slow down filter rates, shorten runs, or penetrate the sand bed, as does ordinary powdered carbon. It is suggested by the manufacturer for use in conjunction with "Black Alum" when and if additional carbon is required for taste elimination. "Filterseed" was developed in Activated Alum's novel "Travelling Laboratory," (pictured above) which has been successfully used in testing its products and studying coagulation of waters and sewages at many plants.

Standard filter alums will also be produced and marketed, as such, by the company in competition with other commercial and special grades of sulphate of alumina, such as high-basic, iron-free," et al.

In the new plant, which has been modernly engineered and built under the direct supervision of F. E. Stuart, president of the company, one is impressed with the flow schemes for production and handling of raw and finished products. From an adjacent acid plant, sulphuric acid flows by gravity to the third floor storage tanks in the alum plant. The bauxite and carbon likewise flow by gravity from storage bins, and throughout the manufacturing stages all production is on a gravity flow basis —only the finished product being bucket-elevated to the packing hoppers and loading floor. With ample capacity, the new plant has 1,600 square feet of floor area and is adequately equipped with the most modern power economizing equipment, making for changes in production speed at will and on operation on a continuous 24 hour flow basis, when required to meet future demands.

The company plans to continue its research and development program, with the benefit of its "Laboratory on Wheels," and has therefore planned the new factory so as to add new products as they are developed. Furthermore, it proposes to manufacture meritorious products which may be developed in whole or in part by others.

As announced in a previous issue, the plant is in charge of Ben. F. Tippins, former Superintendent of Water and Sewerage at Daytona Beach, Fla.—Activated Alum's slogan being—"Chemicals Produced by Water Works Men for Water Works Use."

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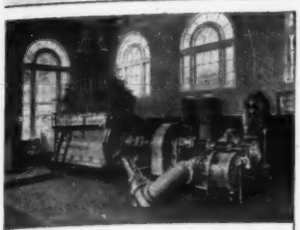
Hydraulic Institute Issues 7th Edition of Pump Standards

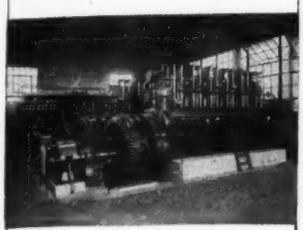
The Hydraulic Institute, a trade association supported by 42 leading American pump manufacturers, has recently issued the 7th Edition of "Standards of Hydraulic Institute" which is a compilation of technical pump and pumping data, good and bad practices in installation and operations of pumps, standardized definitions, terms and practices, and other information of value to engineers, buyers and manufacturers of pumps. The Centrifugal Pump Section presents an illustrated set of definitions of types and parts; discusses standards of volume output, head, power, and the meaning of guaranteed efficiency; presents numerous charts showing relationships between suction lifts, heads, speeds and pump output under a variety of combinations of such conditions; discusses and illustrates proper and improper methods of installing centrifugal pumps, also suction and discharge lines; presents suggestions and instructions for most efficient and trouble free operation.

Other sections deal similarly with Rotary Pumps, Reciprocating Pumps, Deep Well Pumps. Then follows a Code for Testing Pumps; the Use of Gages; Measurements of Power Input. The closing "Data Section" contains friction tables and elaborate charts covering friction data and velocities for water and other fluid materials subject to pumping.

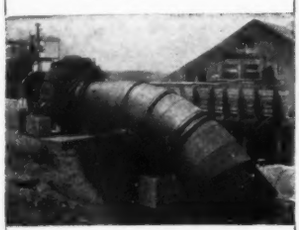
The seven Sections are purchasable singly or as a complete set in one binding for $1.00. The "Centrifugal Pump Section" and "Data Section," singly, are 50 cents each. Publishers—The Hydraulic Institute, 90 West Street, New York City.



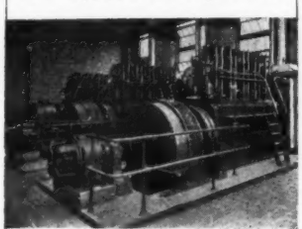
Diesel-engine-driven centrifugal water works pump



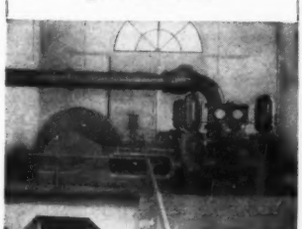
Diesel engine electric generator units



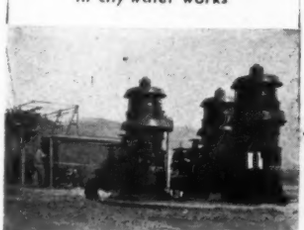
Centrifugal pump for low-head water supply, Diesel-engine-drive



Gas engine electric generator units



Reciprocating duplex pump in city water works



Deep well turbine pumps for city water supply

WORTHINGTON WATER WORKS EQUIPMENT brings the accumulated successful experience of generations . . . to every pumping job . . . under every condition.

The outstanding records of Worthington installations are high lights in water works history.

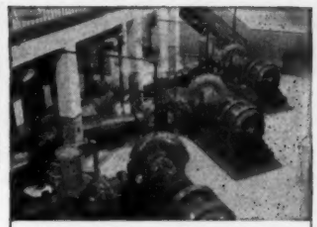
IN addition to equipment for water works, Worthington pumps for main raw sewage units, and for various auxiliary services, will be found in a large percentage of our modern sewage disposal plants. The growing list of recent important contracts placed with Worthington is convincing evidence of this Corporation's position in the field.

For any requirement of head and capacity there is a correct Worthington unit . . . and when conditions call for engine drive, a complete line of Worthington Diesel and Gas Engines is available.

Recently, developments for the conversion of formerly wasted sludge gas to useful power have also found Worthington in a leading position, with many successful installations of its gas* engines . . . selected from a complete line of 30 to 1800 horsepower units which meet all needs . . . from those of the smallest town to the largest city.

In any pumping or power problem . . . Worthington engineers are available for a study of your local conditions, and will submit complete and unbiased recommendations.

** Worthington Gas Engines are convertible to oil fuel operation . . . for service during periods when supply of sludge gas is low.*

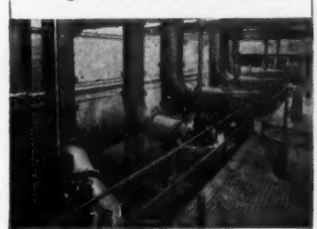


Motor-driven centrifugal pumps in city water works

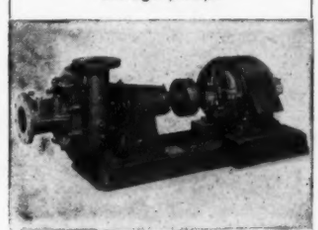
Turbine-driven centrifugal pumps in city water works

Vertical centrifugal pump for water supply, Diesel-engine-driven through right-angle gears

Motor-driven vertical centrifugal sewage and storm water pumps



Motor-driven vertical sewage pumps



Motor-driven Freflo pump for unscreened sewage

WORTHINGTON PUMP AND MACHINERY CORPORATION

General Offices: HARRISON, NEW JERSEY — Branch Offices and Representatives in Principal Cities throughout the World

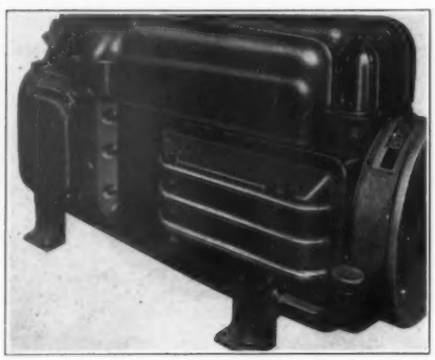
WORTHINGTON

EQUIPMENT NEWS

Novel Crankless Engine (Operates on Diesel Fuel)

It is particularly appropriate that in this special issue for the A. W. W. A. convention in Buffalo that a Buffalo product—Sterling Engine Co.'s new Crankless Oil Engine—be described. It represents something wholly novel in oil burning engines, and is designed for duties which the Diesel type engine is especially well suited to perform.

The Sterling Crankless Engine involves a



Sterling Crankless Oil Engine

perfection of the patent of A. G. Mitchell, famed as inventor of the important Mitchell-Kingsbury thrust bearing so widely used on ocean liners to absorb propeller thrust. This novel engine is an opposed piston engine with four horizontal cylinders containing 8 pistons (four on one side coming to the center to meet the four on the opposite side), the result being that of complete elimination of cylinder heads and poppet valves. With many fewer parts and higher thermal efficiency, starting is easier. Without piston side thrust or crank-shaft, only three main bearings are required. With especial pride, the manufacturer emphasizes the effective uniflow design for scavenging the cylinders with new air, and charging them for the next firing. To two inclined (vertically set) rotating discs opposite each other, the eight reciprocating pistons transmit the explosion power to rotate the horizontal shaft attached at the centers of the discs. This operation can be best understood by thinking of a water meter, the revolving disc of which is driven by the water power. The manufacturer emphasizes the fact that the Sterling Crankless Engine incorporates the simplest movements ever used in an internal combustion engine of any type; employs many fewer parts, has speed range of 400 to 1,200 revolutions; remarkable freedom from vibration; flexibility of control that has been the goal of oil engine designers for more than 30 years, and several additional features.

A new illustrated bulletin "The Sterling Oil Burning Engine," recently issued, makes interesting reading. For a copy, address Sterling Engine Co., (Dep't. W. & S.) Buffalo, New York.

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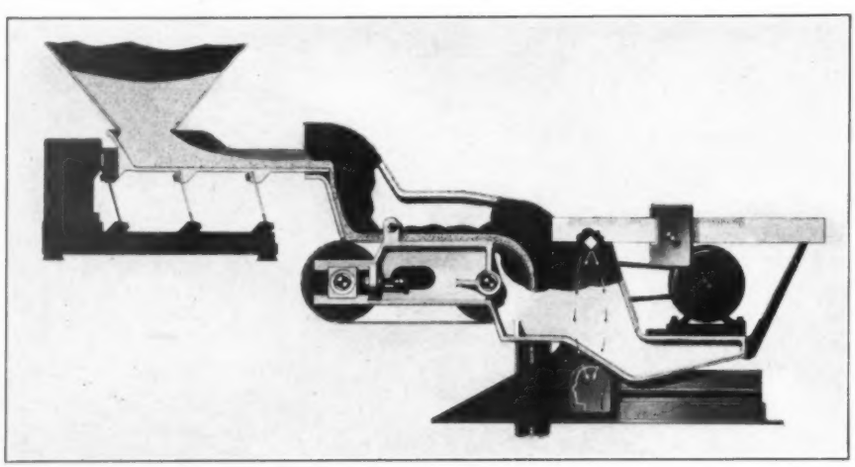
Jeffrey Precision Weighing Feeder

A new precision machine, applicable to the process of continuous weigh-feeding and proportioning, called the "Waytrol," has just been announced by the Jeffrey Manufacturing Co., Columbus, Ohio. This machine combines three important features conducive to dependability and super-accuracy: (1) All-electric vibrating feeding; (2) a synchronous weigh-belt, on a scale beam so pivoted as to receive material at the most sensitive end, and (3) automatic all-electric control, sensitized through a device called the "Electric Brain."



Jeffrey "Waytrol" Feeder

With this unit feeding and weighing are physically separated processes. Furthermore, the rate of feed to the constant speed weigh-belt is in no way dependent on the volume of material handled. It is governed directly—and only—*by weight*. The "Electric Brain," which registers any slight unbalance of the belt and makes instant correction by speeding up or slowing down the supply to the belt is the governing unit. For dustless operation, and to avoid the possibility of error caused by wind pressure, the entire unit is enclosed in steel and glass. It operates from any standard 60-cycle lighting circuit.

"Waytrols" are available in sizes handling from a few pounds to several tons per hour. The manufacturer guarantees that all will weigh and feed to 99 per cent accuracy or better. Bulletin No. 644 pictures and describes the machine, and its applications, in detail. Address Jeffrey Manufacturing Co., Columbus, Ohio.

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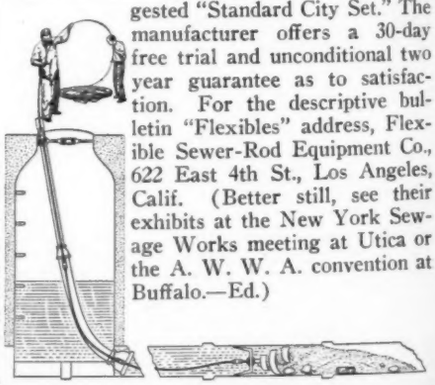
Flexible Sewer Rod

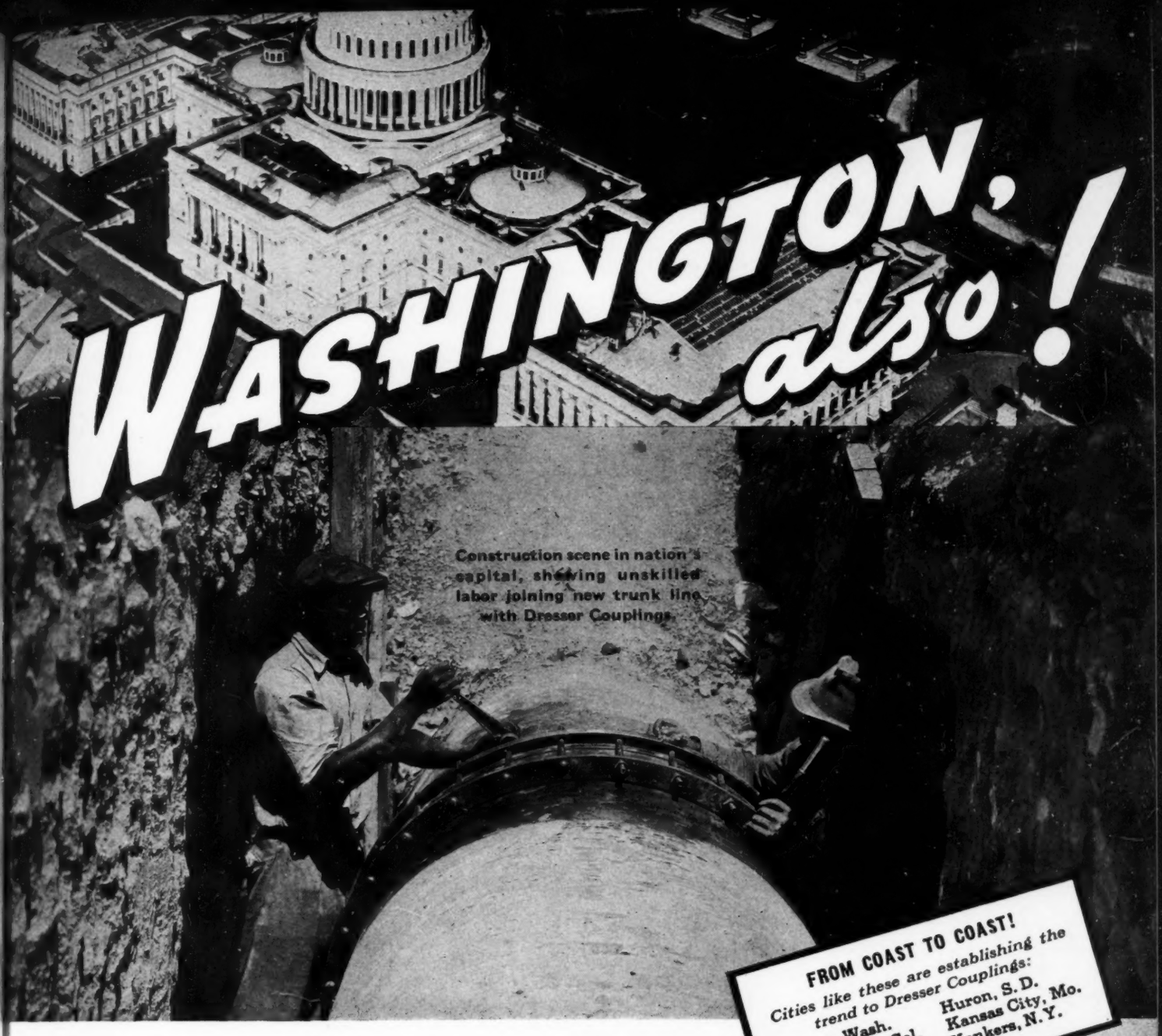
The Flexible Sewer Rod is already known to many of our readers but to many more its announcement constitutes news—especially the improvements, accessories and power drive unit.

Flexible rods of steel come in standard three foot lengths jointed with reinforcing couplings into desired straight lengths. Or may be transported as a coil on a revolving frame which will carry up to 600 feet of flexible rod. A variety of cleaning heads such as cork-screws, augers, spear-heads and the like are available for coping with various stoppages and removal of root-growths. For the "tougher" jobs and long runs turning handles and rachets are provided for securing the unstopping "bite," and the boring through twist on the flexible rod. For speedier work and very long runs use of the portable "Flexible" Power Drive (about the size of a lawn-mower) is suggested by the manufacturer. More efficient is the Power Drive, in the spiral scraping operation, and it has been successfully used in cleaning water mains as well as industrial waste lines, coated with hard lime deposits and the like.

Rods and equipment are cadmium plated to resist rusting. In a well illustrated bulletin, the full line of "Flexible" equipment and its use is pictured. Listed, is a suggested "Standard City Set." The manufacturer offers a 30-day free trial and unconditional two year guarantee as to satisfaction. For the descriptive bulletin "Flexibles" address, Flexible Sewer-Rod Equipment Co., 622 East 4th St., Los Angeles, Calif. (Better still, see their exhibits at the New York Sewage Works meeting at Utica or the A. W. W. A. convention at Buffalo.—Ed.)



Flexible Sewer Rod



Construction scene in nation's capital, showing unskilled labor joining new trunk line with Dresser Couplings.

FROM COAST TO COAST!

Cities like these are establishing the trend to Dresser Couplings:

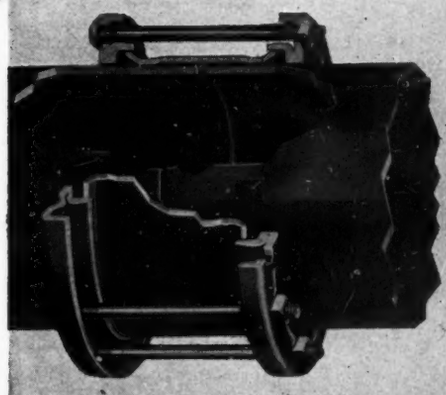
Camas, Wash.
Col. Springs, Col.
Columbus, Ohio
Huron, S. D.
Kansas City, Mo.
Yonkers, N. Y.

Another city where Dresser Couplings are being used to join new water mains is our nation's capital. Several Dresser-coupled lines, in sizes from 18" to 93", have been installed there since 1930. Especially proud are we of the new 31½-37-49⅜" O.D. trunk main laid in 1936, also completely Dresser-coupled.

FIVE REASONS WHY MODERN WATER LINES ARE DRESSER-COUPLED:

1. PERMANENT TIGHTNESS—proved for 50 years, on 150,000 miles of pipe.
2. FLEXIBILITY—normal pipe movements—present in every line—are absorbed.
3. SIMPLICITY—joints are "factory-made"; ordinary labor can install.
4. STRENGTH—predetermined; joints safely withstand any specified pressure.
5. TRUE ECONOMY—a truly lower joint cost throughout the life of the line.

Write for our General Catalog No. 36.

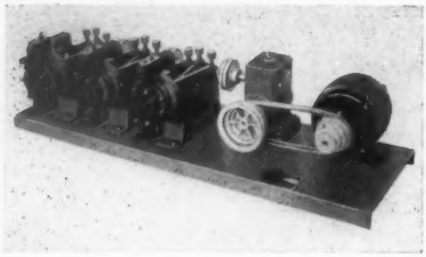


Cutaway view of Dresser Style 38 Coupling, showing working principle. Note that plain-end pipe is used. The resilient gasket, flexing with the pipe, safely absorb pipe movements.

THE MODERN TREND IS TO DRESSER COUPLINGS

S. R. DRESSER MFG. COMPANY, BRADFORD, PA. • *In Canada:* Dresser Mfg. Company, Ltd., 60 Front St., W., Toronto, Ont.

% CHEMICAL FEEDERS %



Quintuplex! ! ! ! !
Quadruplex! ! ! !
Triplex! ! !
Duplex! !
Simplex!

What's perplexing you?

% Proportioneers % are "ganging up" on chemical treatment! Midget Chemical Feeders, grouped together in series as illustrated, are being hailed by perplexed designing engineers as a means of bettering performance and lowering the cost of water plants.

For example, an Atlanta, Ga., engineer proposes the Quadruplex Feeder to serve an Alabama water plant as follows:

UNIT NO. 1—to feed alum ahead of filter to hasten coagulation.

UNIT NO. 2—to feed soda ash ahead of filter, also as a coagulant.

UNIT NO. 3—to feed hypo after the filter to sterilize.

UNIT NO. 4—to give a post-treatment of soda ash for bringing up the pH to avoid corrosive condition of water introduced by previous alum feed; saving the distribution system from red water and corrosion troubles.

Flexible to the extreme in their application, more likely than not a % Proportioneers % chemical feeding device will fit your perplexing need. Send complete details, or ask for Bulletin "PH."

A.W.W.A. — BUFFALO
A welcome awaits you at our booth, also a chance to see just what we have to offer.

% PROPORTIONEERS % Inc.

Associated with Builders Iron Foundry

9 N. Codding Street

PROVIDENCE, R. I.

Ampco Sewer Jointing Compound

Atlas Mineral Products Company, manufacturers of the well known pipe jointing compounds "Mineralead," "Tegul-Mineralead" and "G-K" Sewer Joint Compound, announce the addition of "AMPCO" Sewer Jointing Compound to their line of pipe jointing materials.

"AMPCO" is a sulphur-base compound designed especially for jointing of low pressure lines, such as low-head gravity mains and sewers. By the manufacturers recommended as superior to bituminous compounds under conditions that make good bonding with the latter a gamble, AMPCO does not depend upon adhesion to the pipe to make a good and dependable joint. Dampness, frost or a coating of mud or silt on the pipe do not cause poor joints, and AMPCO joints are root-repellent and leakproof. Before publicly announcing the new product a 6-year period of demonstrated dependability has been had in connection with use on representative municipal sewers. It comes packed in cartons, each containing five 10-pound ingots which melt at 248 deg. F.

For further details and folder describing AMPCO and the method of preparing and pouring AMPCO joints, address Atlas Mineral Products Company, Mertztown, Pa.

▼

Dwyer Made Distr. Mgr. Crane Co.

J. A. Dwyer, manager of the Philadelphia branch of Crane Co., has recently been made district manager of all Crane branches in the Eastern territory. Such includes the New England states, metropolitan New Work, Eastern Pennsylvania, New Jersey, Maryland, and the District of Columbia. A total of eighteen Crane establishments are now under the jurisdiction of Mr. Dwyer. His office is at the New York City branch of Crane Co.

H. S. Officer, manager of the Newark branch, succeeds Mr. Dwyer at Philadelphia, and J. H. Geiss moves from Hempstead, Long Island, to succeed Mr. Officer as manager at Newark.

▼

Columbia Alkali Opens Offices in Cleveland and Boston

The Columbia Alkali Corporation announces the opening of new offices in Cleveland and Boston.

A. E. Shaw

J. E. Dockum

A. E. Shaw becomes district sales manager of northern Ohio, with offices at 3859 Hamilton Avenue, Cleveland, Ohio. J. F. Dockum becomes district sales manager of New England, with offices at 300 Babcock Street, Boston, Mass.

Mr. Shaw since joining the Columbia organization in 1932 has devoted considerable time to promotional work, more recently to the distribution of Columbia's full line of products.

Mr. Dockum, a native New Englander and graduate of the University of New Hampshire, has spent considerable time in various departments of the company. For the last several years his efforts have been entirely in sales and distribution of Columbia's full line of products.

▼

New Balanced Diaphragm Valve

A new, balanced diaphragm valve, developed and manufactured by the McAlear Mfg. Co., of Chicago, is claimed to have the feature of closing off tight, repeatedly, in service on fluids or gases containing foreign matter; being balanced, it will open or close easily. There are no bellows or stuffing boxes, thus preventing all friction. When used on throttling service there are no bad effects from wire drawing.

This valve need not be removed from the line to change the diaphragm, which can be supplied of various compositions, or with a lining, to take care of air, water, gas, acids, or alkalis.

The McAlear Balanced Diaphragm Valve will operate in any position, will not damage from freezing, and can be either hand or motor operated. This new valve is available in sizes of 2 in. and larger. For descriptive bulletin address McAlear Mfg. Co., 1901 S. Western Ave., Chicago.

Air Compressor From Ford Parts

60 cubic feet per minute with one gallon of gasoline per hour!

Operates rock drill, Pavement breaker, digging tools, caulking hammers, backfill tampers, chipping hammers, sand blast, etc.

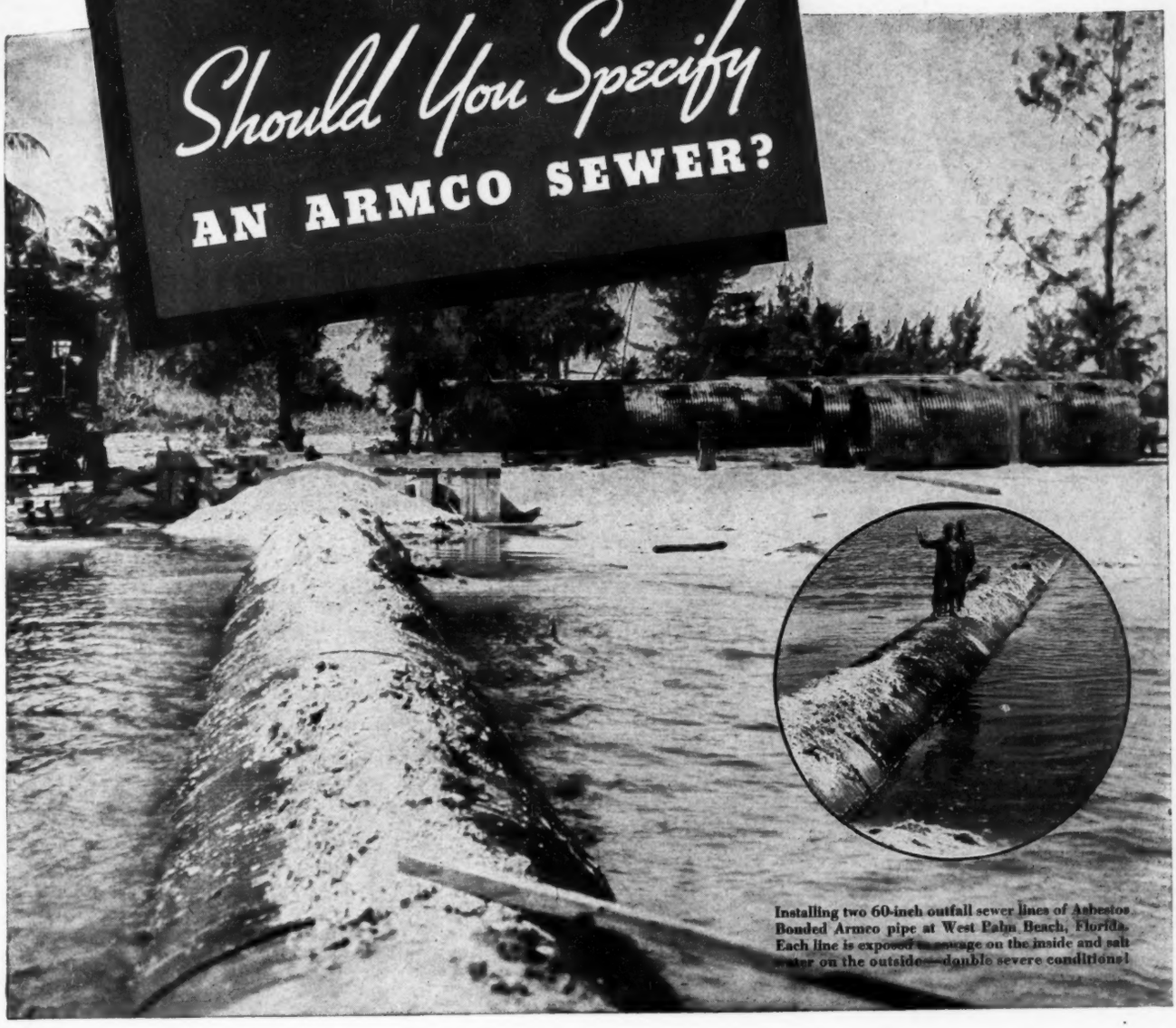
Widely used by Cities, Counties and Public Utilities because of its low cost, economical operation, ease of handling and Ford service.

Available in portable form or as conversion parts for your own Ford motor.

Write for complete literature and prices.

GORDON SMITH & COMPANY
Incorporated
517 Tenth St., Bowling Green, Ky.

WHY *Should You Specify* AN ARMCO SEWER?



Installing two 60-inch outfall sewer lines of Asbestos Bonded Armco pipe at West Palm Beach, Florida. Each line is exposed to sewage on the inside and salt water on the outside—double severe conditions!

2 Good Reasons

WHEN YOU DESIGN a sewer system of Armco corrugated pipe say good-bye to costly structural failures. Even under the most severe loading and foundation conditions, you can depend on this sturdy, flexible pipe to serve as a line *during its full material life.* This asurance comes from 41 years of successful experience with thousands of installations.

Now to the superior *structural* features of corrugated metal pipe Armco has added a high degree of *material* permanence. Many ARMCO Ingot Iron sewers laid nearly *3o years* ago are sound and strong today. Putting a thick bituminous pavement in the bottom has added at least another *12 years* to the life of Armco pipe. And now . . . with a complete bituminous coating permanently "bonded" to the galvanized metal, your durability problem is solved!

Why not call in an Armco drainage engineer and let him explain the advantages of this improved sewer pipe — in terms of your 1937 requirements? Armco Culvert Mfrs. Association, 703 Curtis Street, Middletown, Ohio.

ASBESTOS BONDED • ARMCO PAVED INVERT PIPE

Water Works and Sewerage—May, 1937

MEETINGS SCHEDULED:

May 19—Seattle, Wash. (University of Washington).
Pacific Northwest Sewage Works Ass'n. Sec'y-Treas., Fred Merryfield, Oregon State College, Corvallis, Ore.

May 21—Newark, N. J. (Essex House).
New Jersey Section, A. W. W. A. Sec'y, P. S. Wilson, 325 Washington St., Glen Ridge, N. J.

May 22-23—Victoria, B. C. (Empress Hotel).
Pacific Northwest Section, A. W. W. A. Sec'y, Fred Merryfield, Prof. of C. E., Oregon State College, Corvallis, Oregon.

June 4-5—Utica, N. Y. (Hotel Martin).
N. Y. State Sewage Works Association. Sec'y-Treas., A. S. Bedell, State Dept. Health, Albany, N. Y. (Manufacturers' exhibits a feature of this meeting).

June 7-11—Buffalo, N. Y. (Hotel Statler).
American Water Works Association. (Annual Convention). Executive Secretary, Harry E. Jordan, 29 West 39th St., New York City.

June 16-17—Waukegan, Ill. (Karcher Hotel).
Illinois Association of Sanitary Districts. Sec'y-Treas., G. H. Radebaugh, Urbana, Ill.

June 21-25—State College, Pa. (Penna. State College).
Pennsylvania Sewage Works Association (June 21-23). Sec'y, L. D. Matter, State Dept. Health, Wilkes-Barre, Pa.

Pennsylvania Water Works Operators' Ass'n (June 23-25). (10th anniversary.) Sec'y, I. M. Glace, 22 S. 22nd St., Harrisburg, Pa.

Aug. 18-20—Dearborn, Mich. (Dearborn Inn).
Central States Section, A. W. W. A. (Annual Meeting). Sec'y-Treas., H. Lloyd Nelson, 2437 Koppers Bldg., Pittsburgh, Pa.

Sept. 20-22—Santa Fe, N. M. (LaFonda Hotel).
Rocky Mountain Section, A. W. W. A. (Annual Meeting). Sec'y-Treas., B. V. Howe, State Sanitary Engineer, State Office Bldg., Denver, Colo.

Oct. 4-6—Atlanta, Ga. (Atlanta Biltmore Hotel).
American Public Health Association (Congress). Executive Director, Frank W. Herring, 850 East 58th St., Chicago, Ill.

Oct. 5-8—New York City, N. Y. (Hotel Pennsylvania).
American Public Health Association (Annual Convention). Executive Secretary, Dr. Reginal D. Atwater, 50 West 50th St., New York City.

Oct. 11-14—Austin, Texas.
Southwest Section, A. W. W. A. (Annual Meeting). Sec'y-Treas., L. A. Quigley, Superintendent Water Dept., Fort Worth, Texas.

Oct. 13-15—Atlantic City, N. J. (Haddon Hall).
Pennsylvania Water Works Association (Annual Meeting). Sec'y, Dr. F. Herbert Snow, 327 Telegraph Bldg., Harrisburg, Pa.

Oct. 19-20—Cincinnati, Ohio (Netherland Plaza Hotel).
Ohio Conference on Sewage Treatment (Annual Convention). Sec'y, Bruce M. McDill, Dept. Health, Columbus, Ohio.

Oct. 20-23—Sacramento, Calif. (Senator Hotel and Memorial Auditorium).
California Section, A. W. W. A. (Annual Convention). Sessions and Exhibits, Sec'y-Treas., C. M. Hoskinson, 1140 43rd St., Sacramento, Calif.

Nov. 4-6—Omaha, Neb. (Fontenelle Hotel).
Missouri Valley Section, A. W. W. A. (Annual Meeting). Sec'y-Treas., Earle L. Waterman, Prof. Sanitary Engineering, University of Iowa, Iowa City.

CATALOGS AND LITERATURE RECEIVED

[*Any of the publications reviewed in this section can be secured from or through Water Works and Sewerage, if such be desirable.*]

"What Constitutes the Ideal Aerator?"—Is the question asked and answered in Chicago Pump Co.'s newest and impressively produced bulletin, presenting "Mechanical Aeration Information," directed to engineers designing or revamping activated sludge plants. In discussing the basis of design of mechanical aerators, covered are such pertinent items as—Oxygenation capacity characteristics; Flexibility in purification control and power consumption; Requirements for mixing, flow velocities, surface agitation, sub-zero operation.

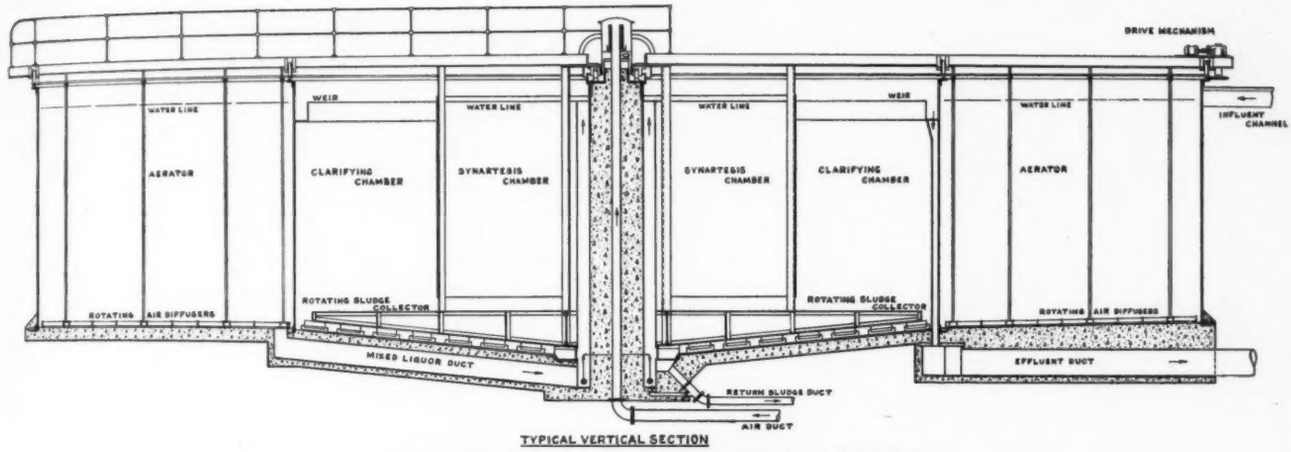
The flexibility in oxygenating capacity of the mechanical "Chicago" Aerator is stressed in lending itself to effective use of the "tapered-aeration" principle, for the successful handling of high and low strength sewages or industrial wastes; enhanced purification control; maximum permissive power economy. Amongst design tables appear (1) "Oxygenation Capacities of Chicago Aerators"; (2) "Aeration Tank Dimensions and Capacity"—including quantities of concrete involved, for square and hexagonal design. Plans, basis of design, and cost, of five representative plants equipped with Chicago mechanical aerators, are also given.

Aside from its impressiveness in color scheme, typography, illustration and scintillating, "cellophane-plated" cover, information in "Chicago" Bulletin 128-L makes it doubly worth asking for. Address, Chicago Pump Co. (Dept. W. S.), 2349 Wolfram St., Chicago.

"Penchlor Acid Proof Cement"—In this little booklet, issued by Pennsylvania Salt Manufacturing Company, the properties, qualities, adaptations and service of Penchlor Acid Proof Cements are described and illustrated. Especially is the product recommended for lining of tanks for manufacture or storage of ferric chloride, or other acidic solutions, with acid proof brick jointed with the acid proof cement. The cement is not recommended, however, for use on concrete or other surfaces as a protective plaster coating. In the rear appear "Useful Facts," which include cement requirements for various conditions and size of tank or vat to be brick-lined Ask for Penchlor Acid Proof Cement—Booklet No. 3, address, Pennsylvania Salt Mfg. Company, Widener Bldg., Philadelphia, Pa.

"Victualic—Pipe Couplings"—Is an illustrated bulletin released by Victualic Company of America, long established manufacturers of the Victualic rubber gasketed pipe couplings which serve as flexible mechanical "joint-locks." This bulletin describes and pictures the component parts of the bolted coupling with housing and single rubber gasket ring designed for pressures to 1000 lbs. per sq. in. as well as for high vacuum. Details are shown for its use on grooved or shouldered-end cast-iron or steel pipes and fittings. Its many applications are illustrated in use and others are listed. Especially adaptable is this narrow coupling for hard-to-get-at-places and jointing under cramped conditions, such as in valve pits, pipe galleries and the like. In the rear are specifications, dimensions tables and illustrated installation instructions. For Bulletin 37-1, address Victualic Company of America, 26 Broadway, New York City.

MALLORY
ROTARY CONCENTRIC COUNTERFLOW
AERATOR SLUDGE FILTER CLARIFIER
UNITS



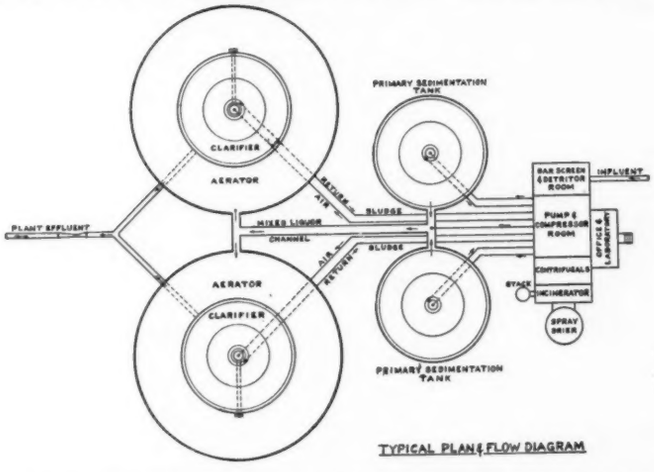
TYPICAL VERTICAL SECTION

PARTICULARLY ADAPTED FOR USE IN

MALLORY
OXIDIZED SLUDGE PROCESS
SEWAGE AND INDUSTRIAL WASTE TREATMENT PLANTS
95% B. O. D. REMOVAL CONTINUOUSLY

LOWER CONSTRUCTION AND OPERATING COSTS

NO CHEMICALS USED



TYPICAL PLAN & FLOW DIAGRAM

PLANT CAPACITIES ACCURATELY RATED IN POUNDS OF B.O.D. REMOVAL

SLUDGE BULKING COMPLETELY ELIMINATED

PROCESS AND APPARATUS LICENSED UNDER MALLORY INVENTIONS

LANCASTER IRON WORKS, INC.
SEWAGE APPARATUS DIVISION
122 EAST 42nd STREET
NEW YORK

MANUFACTURERS OF SEWAGE EQUIPMENT FOR 30 YEARS

"Hydro-Tite-Handbook": — From Hydraulic Development Corporation, well known manufacturers of pipe jointing compounds, has come a booklet of "Useful Information"—just off the press. Expensively and attractively produced, the foreword states that "This booklet is distributed with the hope that it may more fully acquaint engineers and contractors with 'Hydro-Tite'—but, at the same time, prove a source of useful information." The booklet contains much of value furnished by leading authorities or compiled expressly for the publishers. Naturally, it tells much about "Hydro-Tite" and its outstanding characteristics—all in a pleasing and effective manner. There are many tables of useful information and conversion factors; methods of evaluating pipe line capacities (fire flows); "Lessons in Simplified Hydraulics"—with typical problems and their solution; "Every-day" methods of determining the condition and friction coefficients ("C" values) of mains; their capacity friction-created loss of head, and power requirements in pumping through such mains. Specially prepared graphs and diagrams supply the ready means of obtaining such information, without tedious calculations, and other facts in addition. Merely for the asking, a copy of "Useful Information" can be had from Hydraulic Development Corporation, 50 Church St., New York City.

"Sludge Pumps":—In a new bulletin Ralph B. Carter (pump specialist for 35 years) presents pertinent reasons *"Why Engineers Specify Carter Sludge Pumps."* And, so, the cover title. The No. 1 reason: Oil immersed reduction gears of herringbone design, and flywheel-sprocket with slow speed wrap-around chain drive, are jointly contributory to the telling distribution of shock-load at the change in stroke direction of the rugged Carter plungers. Other reasons: Flanged connections throughout; easily renewable seats of the well known "Humdinger" time tested rubber ball-valves; automatic but economical plunger lubrication, automatically maintained resilient (under-plunger) air-cushion, to preclude pounding. With numerous clarifying photographs and line drawings the specifications presented cover one, two and three cylinder, variable speed and adjustable stroke Carter pumps to handle from 30 to 515 g.p.m., at 25 to 100 per cent capacity variations. At the end, a series of "Questions and Answers" emphasize social pertinent fine-points of sludge pumping requirements. For a copy of "Why Engineers Specify Carter Pumps," address Ralph B. Carter, "Humdinger Place"—Hackensack, N. J.

"Morris Double-Suction Centrifugals"—Are the subject of a new bulletin on the Morris Double-Suction Horizontally-split centrifugal pumps for which is claimed remarkably high efficiency over wide ranges of capacities. Concisely outlined are features of impellers and castings responsible for improved efficiencies; the sturdy end-thrust bearings; stuffing boxes; machining and fitting—which have all contributed to raising efficiencies. A complete table of ratings appears also. For Bulletin 164, address Morris Machine Works, Baldwinsville, N. Y.

"What Value Sludge?"—might be the title of a Royer Co. leaflet, which cites the true values of dried sewage sludges as soil improvers, beyond those revealed in chemical analyses. The values of disintegrated sludge at a profitable price, as compared to lumpy (hard to get rid of) unprepared material, are set forth. For a copy, address C. G. Wigley, 3108 Atlantic Ave., Atlantic City, N. J.

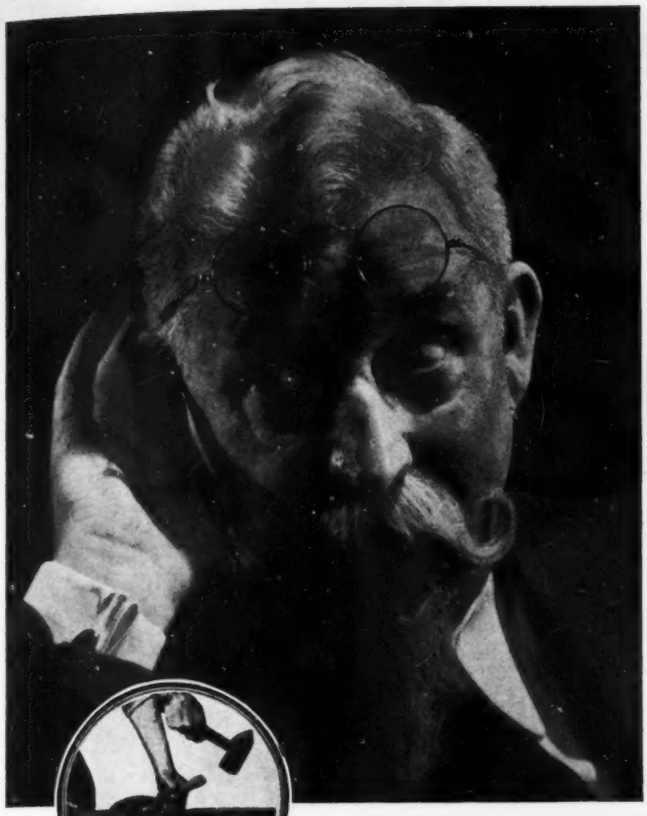
"Pumps—Deep Well Turbines"—Is an expensively produced and profusely illustrated bulletin from Victor Equipment Company's Kimball-Krough Pump Division—(for 70 years builders of pumps of many types) who stress their long sustained policy of "tailor-made" pumps for specific installations and duty. Features of their deep-well turbine pumps, strainers, pump heads and bearings are discussed and adequately illustrated as is efficiency ratings and the like. An impressive list of "K-K" Pump users is exhibited and installations pictured. In the appended section of "Useful Data" are friction and power conversion tables. This bulletin (No. 260) deals with oil lubricated pumps exclusively; a companion bulletin (No. 270) as effectively describes "K-K" water lubricated pumps with rubber bearings. For bulletins 260 and 270 address Victor Equipment Company (Pump Division) 512 Harrison St., San Francisco.

"Yeomans Pumps"—Is a new catalog on Yeomans pumps and pumping equipment, ejectors and compressors for water and sewage which is put together as a guide to engineers and architects seeking pumping equipment for whatever purpose. The booklet is arranged in a simple and easy-to-follow style. Yeomans Screenless Automatic Sewage Ejector and the long and well known Shone air-operated sewage ejector system are amongst the several more important units of equipment. For a copy of the useful "Architects and Engineers Book of Yeomans Pumps" address Yeomans Brothers Company, 1433 Dayton St., Chicago.

"Solencid Valves"—Is a new 32-page illustrated catalog from Automatic Switch Company, pioneers in the development of valves operated by the solenoid-magnet for the purpose of obtaining remote or automatic valve operations. The new catalog discusses the "Selection of the Proper Valve," illustrates the principal methods of control of Solenoid Valves and electrical connections. Then follows the complete catalog of "ASCO" packed and packless types of valves for a variety of services. Attention is directed to the inclusion of 10 new items and many price reductions since the issue of the previous catalog, dated 1935. Ask for Catalog No. 20—Automatic Switch Company, 154 Grand St., New York City.

"Coleman pH Electrometer"—Is a leaflet descriptive of the Coleman pH instrument (Electrometer) which features rugged sealed-glass electrodes, reads direct in pH units, and has an automatic compensator for temperature changes. Features of especial interest are ruggedness, dependability, simplicity and economy of operation and the reasonable price of four different models. (The Coleman has been described somewhat in detail on this page of a previous issue—that of July, 1936—Ed.) For a copy of Bul. 372 and the new booklet, "Measuring pH with the Glass Electrode," address Wilkins-Anderson Co., 111 North Canal Street, Chicago, Ill.

"Concrete Pipe Sewer in Tunnel"—Is the subject of an American Concrete Pipe Association engineering bulletin, which describes and illustrates the design, most practical methods and economy of constructing sewers of concrete pipe in tunnel, rather than open cut trench. Specific installations are cited and the recent project at Oak Park, Ill., involving 24 to 42-inch pipe is briefly described, as are the Wanaque, N. J., Baltimore, Md., and New York City projects, involving reinforced concrete water pipes in tunnel. For a copy of Bulletin 11-1936 and other Bulletins of the Association, address M. W. Loving, Secy., American Concrete Pipe Association, 33 W. Grand Ave., Chicago, Ill.



"DID YOU SAY *that* PERMANENT

McWANE 2" CAST IRON PIPE

COSTS ONLY A FEW PENNIES MORE PER FOOT?"

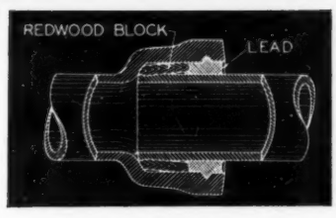
That's another pleasant surprise . . . you pay no big premium to insure the *permanence* of your small mains with corrosion-resisting *cast-iron* pipe.

Average costs time and again show that McWane 2" *cast-iron* mains can be laid for only a few *pennies* more per foot than a short-lived substitute. WHICH? Pennies saved in first cost . . . or pennies for permanence . . . pennies to put an end to maintenance, water losses, replacements.

Investigate!

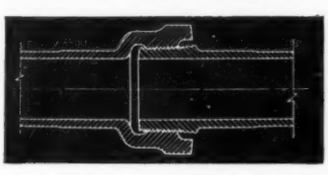
A. W. W. A. week of June 7th, Buffalo, McWane Booth No. 30

McWANE PRECALKED JOINT



For easy, quick installation with unskilled labor. The Precalked materials are already in the bell. No lead melting or pouring. Just socket the spigot and calk!

OVERSIZE MALE and FEMALE THREADED INTERMEDIATE JOINT



Always used as the intermediate joint in factory - assembled 18-ft. lengths of McWane 2" cast-iron pipe for it is the only joint as strong and permanent as the pipe itself.

Sand Cast Inside and Outside

McWANE CAST IRON PIPE COMPANY

BIRMINGHAM, ALA SIZES 1¼" THROUGH 12"

Chicago, Dallas, Denver, Kansas City, New York. Portland, Ore., Salt Lake City, San Francisco, Los Angeles

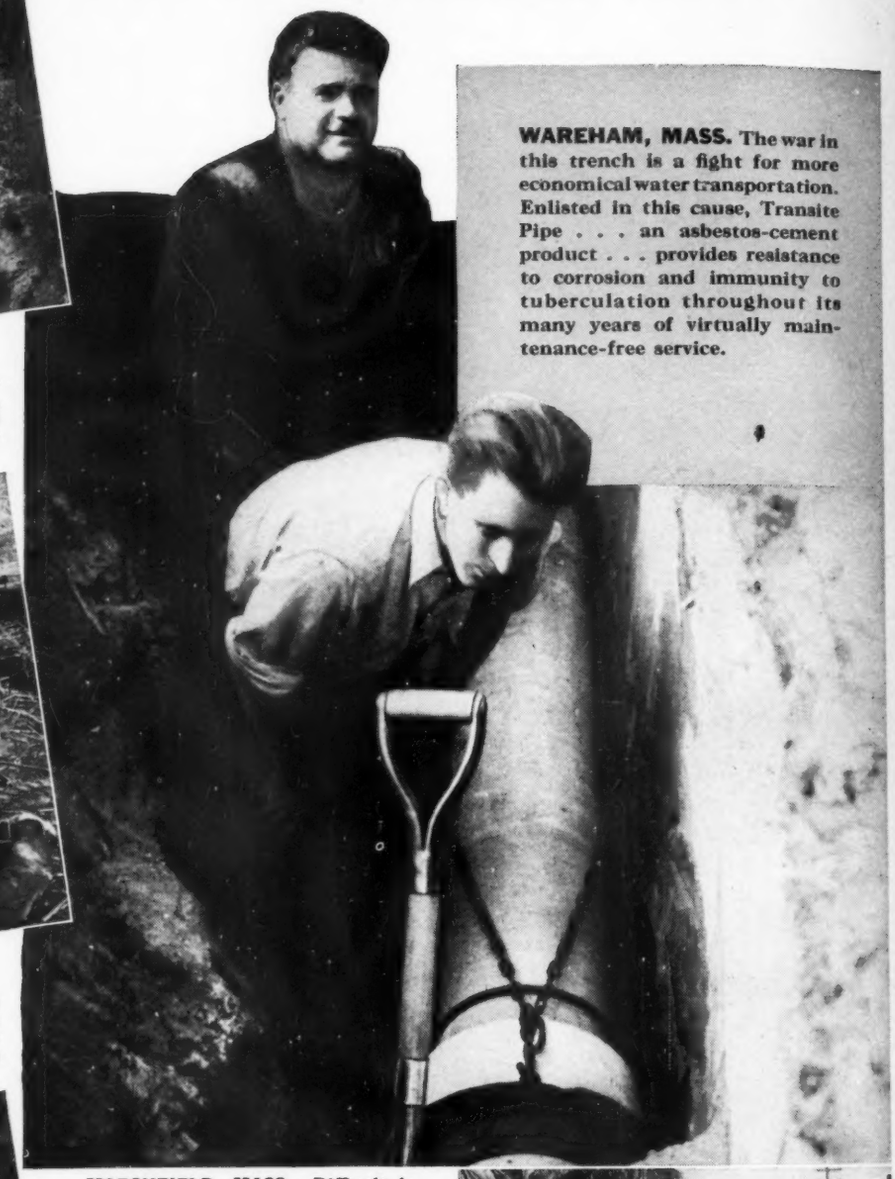
"Sewage and Sludge—Its Measurement, Control and Chemical Treatment."—In a new 23 page bulletin, as interesting and illuminating as it is fresh from the print shop, Builders Iron Foundry—(producers of the first Venturi Tube)—sets forth many pertinent and timely facts concerning newer developments in the measuring of sewage and sludge flows. Also, presented are facts pertaining to the exact control and economy of chemical feeding through the use of Venturi tube actuated equipment and chemical feeders. Herschel, the inventor of the Venturi Tube (1887), would find much of interest in the applications of his invention in modern sewerage practice—especially in the diagrammatic layout of a modern treatment plant, showing the numerous locations of uses of Venturi Tubes. Furthermore, those devices actuated by his tubes take the guess out of expensive modern sewage treatment and keep dollars in the taxpayers pocket. The bulletin presents a good discussion of the characteristics, and applications of Venturi Tubes, Parshall Flumes, Kennison Nozzles, Weirs and the proper selection of primary elements, and indicating and recording units. Then follows a section devoted to performance, and adaptations of the Chronoflo Meter. Another deals with chemical proportioning feeders (solution and dry types), automatically controlled through Chronoflo Power units actuated by the flow measuring device. The closing section is devoted to "Suction Well Level and Pump Rate Control" through a new adaptation of the Chronoflo Rate Setter. Attractively put together and more educational than commercial, engineers will enjoy a perusal of B.I.F. Bulletin 287. Address, Builders Iron Foundry, 9 Codding St., Providence, R. I.

"DIGGING IN"

APOLLO, PA. On this typical water-works job, Transite Pipe...the modern, non-tuberculating water carrier...will *permanently* maintain its initial flow coefficient of C-140.

SOUTH RIVER, N. J. The elimination of all mechanical equipment (except on the largest sizes) is a big factor in the low installation cost of Johns-Manville Transite Pressure Pipe.

HUNTSVILLE, MO. Another municipality protects its water-pipe system against corrosion and tuberculation by the use of non-metallic, virtually maintenance-free Transite Pipe.



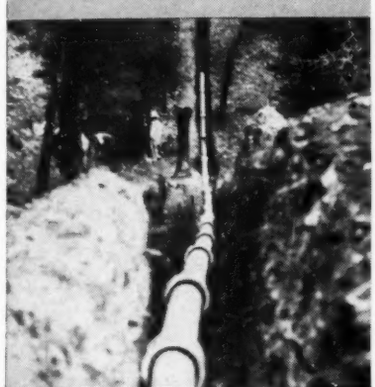
WAREHAM, MASS. The war in this trench is a fight for more economical water transportation. Enlisted in this cause, Transite Pipe . . . an asbestos-cement product . . . provides resistance to corrosion and immunity to tuberculation throughout its many years of virtually maintenance-free service.

MARSHFIELD, MASS. Difficult installations like this are made easy with Transite Pipe. With its Simplex Couplings, rapid assembly is assured.

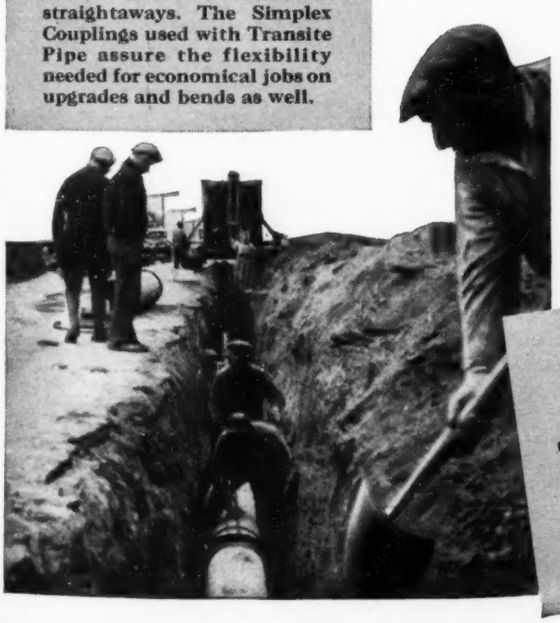
MIAMI, FLA. An asbestos-cement product, Transite Pipe provides the lasting resistance to corrosive soil action always a pre-eminent problem in locations like this.

...for New Victories!

TUCSON, ARIZ. Here, as on every installation, Johns-Manville Transite Pipe's asbestos-cement composition provides maximum assurance of lasting, trouble-free service.



BASTROP, TEX. Ease of installation is not confined to straightaways. The Simplex Couplings used with Transite Pipe assure the flexibility needed for economical jobs on upgrades and bends as well.



PAWTUCKET, R. I. Note the narrowness of the trench...accounted for by the Simplex Couplings on this Transite Pipe installation. These couplings need no caulking... make for rapid assembly.

In defense of economical water supply, Transite Pipe carries on its successful fight against destructive agencies that shorten the effective life of ordinary water pipe

WARS may come and go, but wherever water must be carried, pipe lines wage a perpetual underground battle against corrosion and tuberculation . . . major enemies of permanently effective water-supply systems.

Each passing day...on some new front . . . Transite Pipe, in defense of economical water transportation, "digs in" for another victory. An asbestos-cement product, this modern water carrier offers *lasting* resistance to corrosive soil action, absolute immunity to tuberculation. And, as a result . . .

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Transite Pressure Pipe's initial flow coefficient is conservatively given as C-140. With tuberculation a physical impossibility, this pipe's delivery capacity remains pegged at that high figure indefinitely. And the chance of leaks offsetting this invaluable advantage is reduced to a minimum. For the Simplex Couplings used on Transite Pipe are bottle-tight.

Virtually Maintenance-Free!

Because of the permanence of the two imperishable materials from which it is made, Transite Pipe's effectiveness as a water carrier is maintained at practically no upkeep. Its immunity to tuberculation eliminates shutdown and clean-out expenses. And this, coupled with its unusual resistance to corrosion, means years of virtual freedom from maintenance.

Savings Begin at Installation!

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For complete details on the characteristics of Transite Pipe and the reductions its use assures in pumping, maintenance and installation costs, write to Johns-Manville, 22 East 40th Street, New York City.

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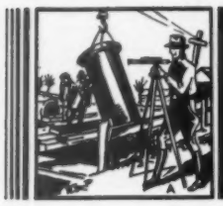

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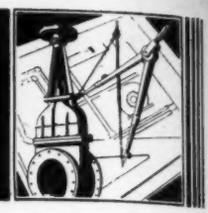

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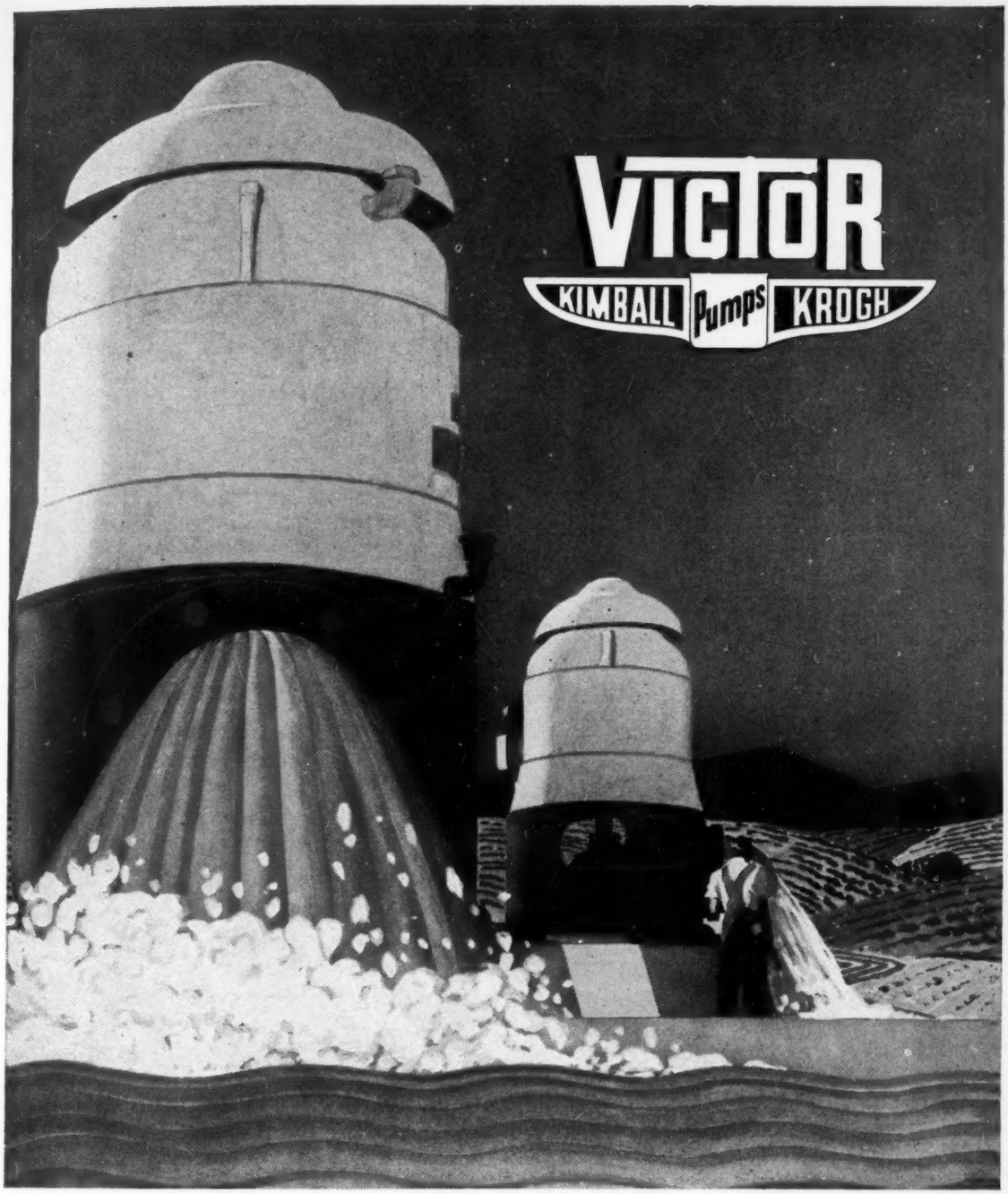

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Water Works and Sewerage—May, 1937

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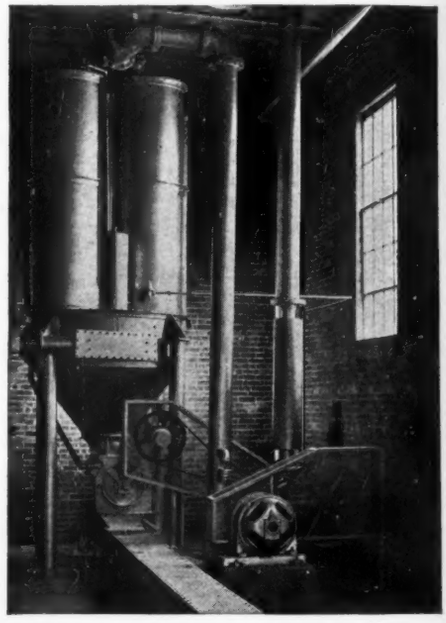

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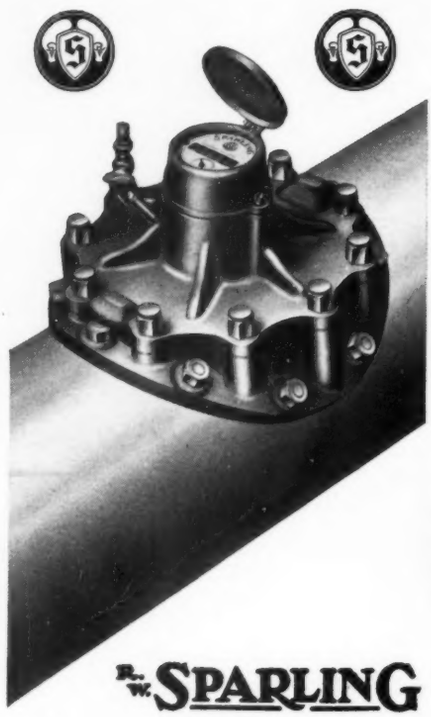

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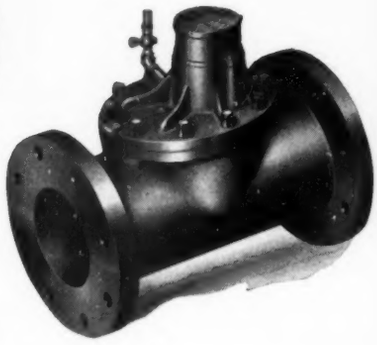

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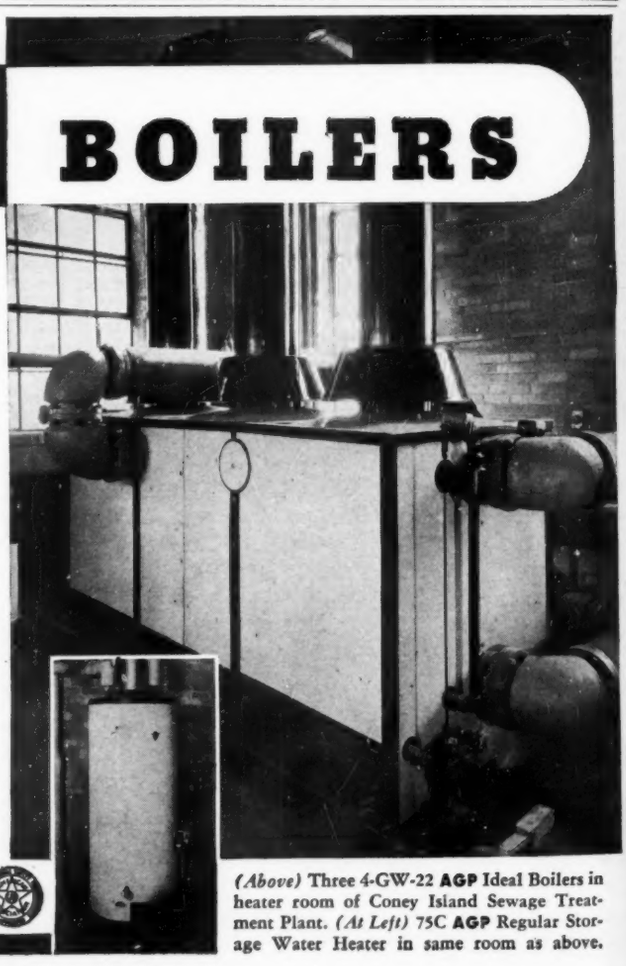

(Above) Three 4-GW-22 **AGP** Ideal Boilers in heater room of Coney Island Sewage Treatment Plant. *(At Left)* 75C **AGP** Regular Storage Water Heater in same room as above.

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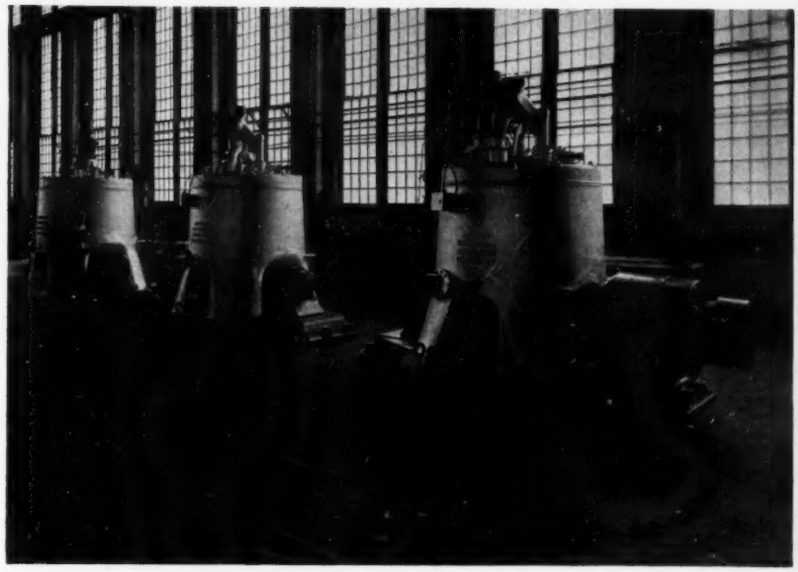

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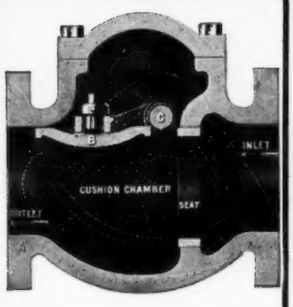

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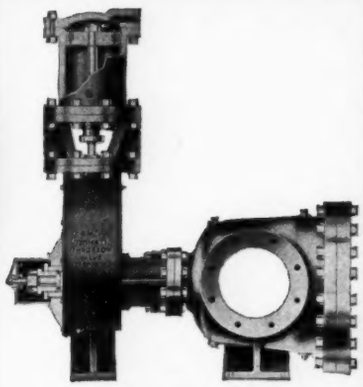

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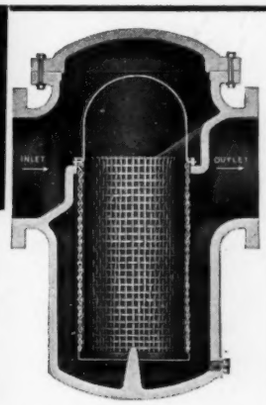

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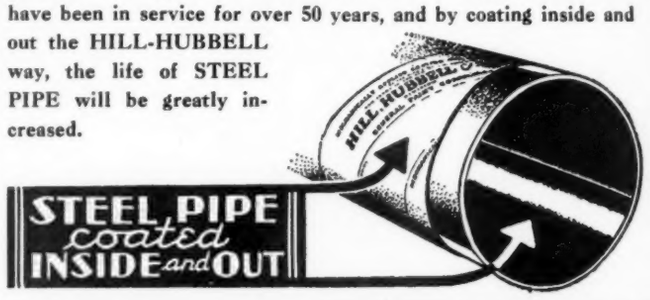

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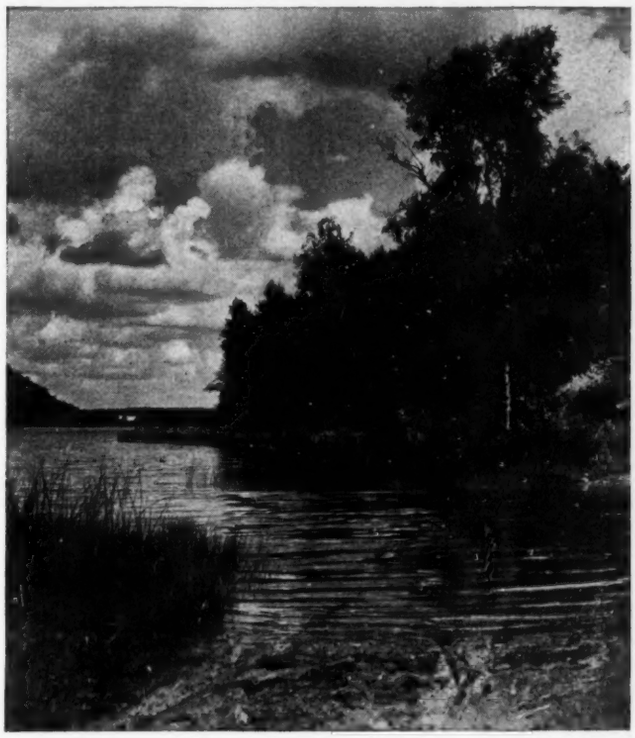

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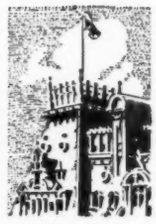

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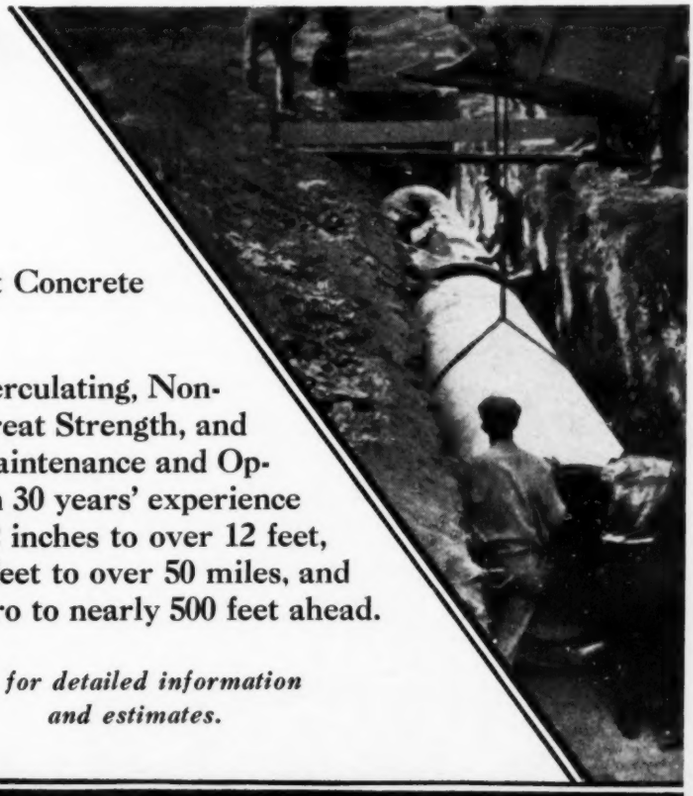

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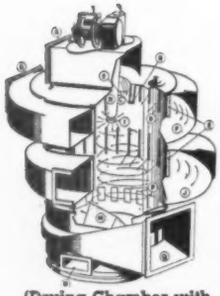

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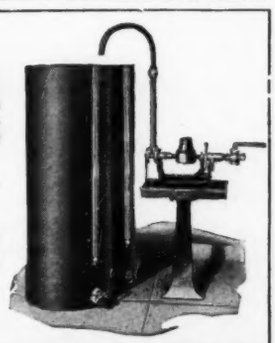

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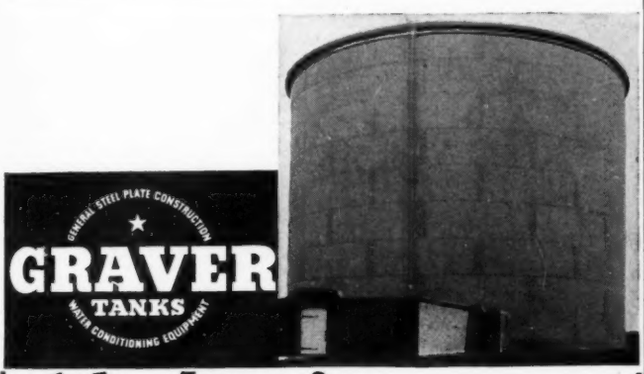

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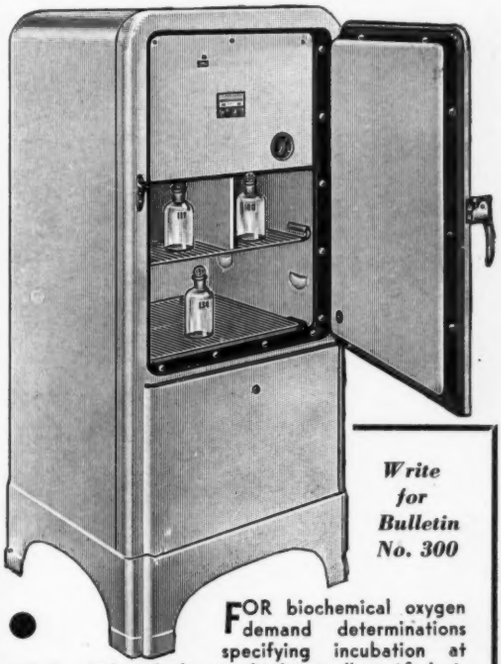

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WATER WORKS
& SEWERAGE

REFERENCE
and
DATA SECTION

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1937

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A Record Making Year!

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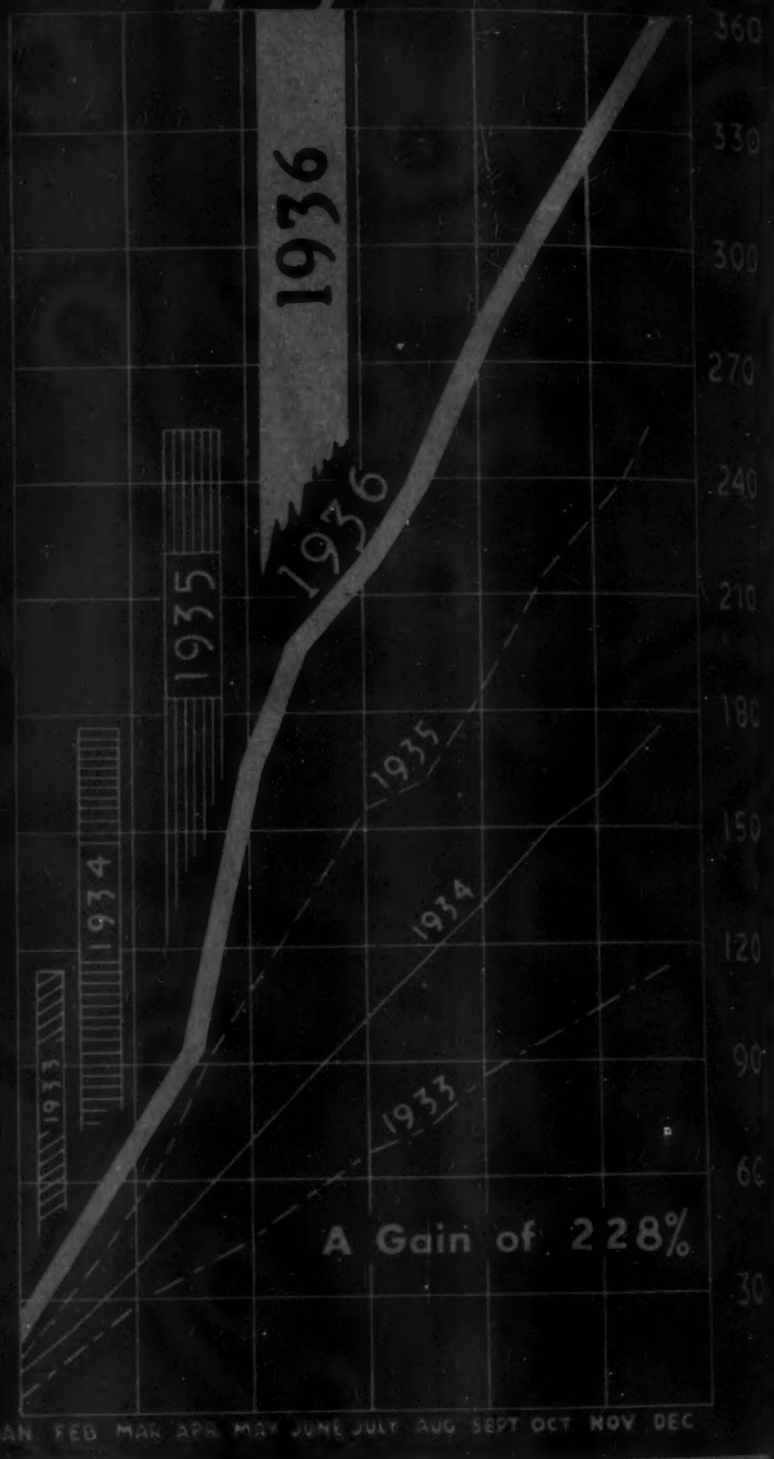

First 5 Issues of 1936 Carried 168 pages
First 5 Issues of 1937 Carried 238 pages

Average gain of 14 pages per issue over 1936

The 17 issues, January, 1936, to May, 1937, have carried advertising for 157 different manufacturers of Water Works and Sewerage materials and equipment. 121 manufacturers are represented in this May issue.

WATER WORKS & SEWERAGE

400 West Madison Street, Chicago — 155 East 44th Street, New York

FOREWORD

GILLETTE PUBLISHING COMPANY presents herewith the Reference and Data Number of WATER WORKS AND SEWERAGE.

This section has been prepared by Mr. L. H. Enslow, Editor of Water Works and Sewerage, and gives the equivalent of a handbook of data on the design, construction, operation and maintenance of water works and sewerage systems.

The contents are carefully selected matter from the files of Water Works and Sewerage and from other sources named in the text. In addition, a considerable effort has been made to secure the latest hydraulic tables and standards and the most economical methods. In a word, the same conscientious work has been put into the preparation of the section as would be expected in a book devoted exclusively to the same purpose.

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Although this index is not published as a COMPLETE index of all materials and equipment used in the Water Works and Sewerage fields—it really is a very comprehensive list of products. It includes equipment and materials produced or marketed in this field by 157 manufacturers who have used WATER WORKS AND SEWERAGE in advertising such products during 1936 and 1937. Of these 157 manufacturers you will find the advertisements of 121 in this issue.

ABRASIVES
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

ACID, HYDROCHLORIC
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Merrimac Chemical Co., Boston, Mass.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACID, SULPHURIC
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACTIVATED AND BLACK ALUM
Activated Alum Corp., 80 Broad St., New York City.

ACTIVATED CARBON
Cliffs-Dow Chemical Co., Marquette, Mich.
Industrial Chemical Sales Co., 230 Park Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bros., 216 Pearl St., New York City.

ACTIVATED SLUDGE PLANTS
Carborundum Co., Niagara Falls, N. Y.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Norton Co., Worcester, Mass.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Simplex Valve & Meter Co., Philadelphia, Pa.

AERATION APPARATUS
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lancaster Iron Works, 122 E. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Sanitary Service, 155 E. 44th St., New York City.
Norton Co., Worcester, Mass.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland, Philadelphia, Pa.
Vogt Mfg. Co., Louisville, Ky.

AIR TOOLS, CONSTRUCTION
Worthington Pump & Machy. Corp., Harrison, N. J.

ALLOY BODIED VALVES
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.

ALLOY CAST IRON PIPE AND FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J.

ALUM, AMMONIA
Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUM, BLACK
Activated Alum Corp., 80 Broad St., New York City.

ALUM, FILTER, COMMERCIAL, IRON-FREE
Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUMINUM SULFATE
Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Merrimac Chemical Co., Boston, Mass.
Penn. Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIA
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIA, ANHYDROUS & AQUA
The Barrett Co., 40 Rector St., New York City.
Great Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City.
Merrimac Chemical Co., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIATORS
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Pardee Engineering Co., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

ANALYTICAL WARE
Carborundum Co., Niagara Falls, N. Y.
Eimer & Amend, 18th and 3rd Ave., New York City.
Norton Co., Worcester, Mass.
Phipps & Bird, 915 E. Cary St., Richmond, Va.

ANTHRAFILT
Hudson Coal Co., Scranton, Pa.

ASBESTOS-CEMENT PIPE
Eimer & Amend, 18th and 3rd Ave., New York City.
Johns-Manville Co., 22 E. 40th St., New York City.

ASH AND COAL HANDLING MACHINERY
Chain Belt Co., Milwaukee, Wis.
Combustion Engrg. Co., 200 Madison Ave., New York City.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Rheolaveur Co., Pittsburgh, Pa.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Syntron Company, 400 N. Lexington Ave., Pittsburgh, Pa.

ASPIRATORS
Vogt Mfg. Co., Louisville, Ky.

AUTOMATIC FILTER AND SOFTENER CONTROLS
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.

BACK FILLERS
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BAR SCREENS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.

BEARINGS
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BELTS, SEWER PIPE
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

BINS, STEEL
Blaw-Knox Company, Pittsburgh, Pa.
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Works, 2198 Old Colony Bldg., Chicago, Ill.
Greundler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BINS, STORAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BLACK ALUM
Activated Alum Corp., 80 Broad St., New York City.

BLEACHING POWDER
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

BOILER FEED PUMP CONTROL
Automatic Primer Co., 113 W. Washington St., Chicago, Ill.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.

BOILER FEEDWATER TREATMENT
Activated Alum Corp., 80 Broad St., New York City.
Dorr Co., 570 Lexington Ave., New York City.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
La Motte Chem. Prod. Co., Baltimore, Md.
Merrimac Chem. Co., Boston, Mass.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

BOILER FURNACE, BRICK
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

BOILER PLANT ACCESSORIES
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York City.
So. Bend Foundry Co., So. Bend, Ind.

BOILERS, GAS

American Gas Prod. Corp., 40 W. 40th St., New York City.

BOILERS, STEAM

Combustion Engrg. Co., 200 Madison Ave., New York City.

BOILER WATER CONTROL EQUIPMENT (pH & PHOSPHATE)

Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.

BOILER WATER PURIFICATION APPARATUS

Dorr Co., 570 Lexington Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

BOXES, VALVES, ROADWAY, MITER

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
M. & H. Valve & Fittings Co., Anniston, Ala.
Modern Iron Works, Quincy, Ill.
Mueller Co., Decatur, Ill.

BRACES, TRENCH, EXCAVATION

Edelblute Mfg. Co., Reynoldsville, Pa.
Templeton-Kenly & Co., 1020 S. Central Ave., Chicago, Ill.

BRAKES, MAGNETIC, MECHANICAL, HYDRAULIC

The Clark Controller Co., 1146 East 152nd St., Cleveland, Ohio.

BREECHINGS, STEEL

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BRICKS, ACID PROOF

Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

BUCKET LOADERS

Barber Greene Co., Aurora, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

BUCKETS, CLAMSHELL

Blaw-Knox Co., Pittsburgh, Pa.

BUCKETS, DREDGING & EXCAVATING

Blaw-Knox Co., Pittsburgh, Pa.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

BUCKETS, SEWER

Champion Corp., Hammond, Ind.

BUFFER SOLUTIONS & MIXTURES

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Prod. Co., Baltimore, Md.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.

CALCIUM HYPOCHLORITE

Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Co., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CALKING MACHINES AND TOOLS

Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

CARBON-ACTIVATED

(See Activated Carbon.)

CARBONATORS

Carborundum Co., Niagara Falls, N. Y.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Norton Co., Worcester, Mass.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

CASINGS & COVERINGS, STEAM PIPES

Johns-Manville, 22 E. 40th St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
A. Wyckoff & Son Co., Elmira, N. Y.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.

Blaw-Knox Co., Pittsburgh, Pa.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
So. Bend Foundry Co., So. Bend, Ind.
U. S. Pipe & Foundry Co., Burlington, N. J.

CASTINGS, MUNICIPAL

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Lynchburg Foundry Co., Lynchburg, Va.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
McWane Cast Iron Pipe Co., Birmingham, Ala.
So. Bend Foundry Co., So. Bend, Ind.
U. S. Pipe & Foundry, Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

CASTINGS, SPECIAL

Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Mueller Brass Co., Streamline Pipe & Fittings Div., Port Huron, Mich.
U. S. Pipe Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

CATCH BASINS, CORRUGATED IRON

Armco Culvert Mfrs. Assn., Middletown, Ohio.

CAUSTIC SODA

Belle Alkali Co., Charlestown, W. Va.
The Columbia Alkali Corp., Barberton, Ohio.
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Wks., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CEMENT

Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

CEMENTS, ACID PROOF

Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CEMENTS, SEWER PIPE

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

CEMENTS, WATER LINES

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CEMENTS, WATER MAINS

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.

CENTRIFUGE EQUIPMENT

Amer. Centrifugal Corp., 115 Broadway, New York City.

CHAINS, CONVEYOR

Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL CONVEYING EQUIPMENT

Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

CHEMICAL FEEDING EQUIPMENT

Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Fuller Co., Catasauqua, Pa.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Omega Mach. Co., 4010 Penn Ave., Kansas City, Mo.
Pardee Engineering Co., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Wallace & Tiernan, Inc., Newark, N. J.
Wilson Chem. Feeders, 110 W. Washington St., Buffalo, N. Y.

CHEMICAL PROPORTIONEERS

International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., Philadelphia, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chem. Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHIMNEYS

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CHLORIDE, FERRIC

Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Innis-Speiden & Co., 117 Liberty St., New York City.
Niagara Alkali Wks., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORIDE OF LIME

Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Niagara Alkali Wks., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORINATORS

Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Filclor Co., 59th & Upland Sts., Philadelphia, Pa.
Filtration & Water Softening Pty. Ltd., Melbourne, Australia.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
Pardee Engineering Co., Long Island City, N. Y.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan, Inc., Newark, N. J.
Wilson Chem. Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHLORINE, LIQUID

Belle Alkali Co., Charlestown, W. Va.
The Columbia Alkali Corp., Barberton, Ohio.
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Monsanto Chem. Co., St. Louis, Mo.
Niagara Alkali Co., 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORINE CONTROL EQUIPMENT

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Rascher & Betzold, Inc., 829 Orleans St., Chicago, Ill.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

CHUTES, STEEL & COAL

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE

Amer. Cast Iron Pipe Co., Birmingham, Ala.
McWane Cast Iron Pipe Co., Birmingham, Ala.
S. R. Dresser Mfg. Co., Bradford, Pa.

CLAMPS AND SLEEVES—RIVER

S. R. Dresser Mfg. Co., Bradford, Pa.

CLAMPS, BELL JOINT

S. R. Dresser Mfg. Co., Bradford, Pa.
M. B. Skinner Co., So. Bend, Ind.

CLAMPS, PIPE REPAIR

S. R. Dresser Mfg. Co., Bradford, Pa.
M. B. Skinner Co., So. Bend, Ind.

CLARIFIERS, SEWERAGE AND WATER

Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lancaster Iron Wks., 122 E. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CLOROBEN

Cloroben Corp., 90 Forrest St., Jersey City, N. J.

COAGULANTS

Merrimac Chem. Co., Everett Station, Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

COAGULATING EQUIPMENT

Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Intl Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.

COAGULATION CONTROL CHEMICALS

Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
La Motte Chem. Prod. Co., Baltimore, Md.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Wallace & Tiernan Co., Newark, N. J.

COAL ANTHRAFILT

Hudson Coal Co., Scranton, Pa.

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD

Ebony Paint Mfg. Co., 2925 E. 18th St., Kansas City, Mo.
General Paint Corp., Cleveland, Ohio.

Inertol Co., Inc., 401 Broadway, New York City.
Tar & Chem. Div., Koppers Co., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

COCKS, CURB, METER, CORPORATION, ETC.
Chase Brass & Copper Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Union Water Meter Co., Worcester, Mass.

COLLECTORS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Dracco Corp., Cleveland, Ohio.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York City.

COMMINUTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATOR
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

COMPRESSORS, AIR
Fuller Co., Catasauqua, Pa.
Gordon Smith & Co., Bowling Green, Ky.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONCRETE
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

CONCRETE BREAKERS
Novo Engine Co., Lansing, Mich.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

CONCRETE HARDENER
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.

CONDENSERS
Amer. Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTROLLERS, AUTOMATIC, ELECTRIC
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Wallace & Tiernan Co., Newark, N. J.

CONTROLLERS, FLOW, LEVEL, PRESSURE, RATIO, TEMPERATURE
Automatic Primer Pump Co., 113 W. Washington St., Chicago, Ill.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

CONVEYORS AND CONVEYING EQUIPMENT
Barber-Greene Co., Aurora, Ill.
Chain Belt Co., Milwaukee, Wis.
Combustion Engrg. Co., 200 Madison Ave., New York City.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Pittsburgh, Pa.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

CONVEYORS—VIBRATORY—ELECTRIC
Jeffrey Mfg. Co., Columbus, Ohio.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

COPPER AND BRASS
American Brass Co., Waterbury, Conn.
Chase Brass & Copper Co., Inc., Waterbury, Conn.

COPPERAS
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.

COPPER SULPHATE
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

COPPER TUBE, FLEXIBLE
American Brass Co., Waterbury, Conn.
Chase Brass & Copper Co., Inc., Waterbury, Conn.
Mueller Brass Co., Port Huron, Mich.

COUPLINGS AND CONNECTIONS, PIPE
S. R. Dresser Mfg. Co., Bradford, Pa.
Mueller Co., Decatur, Ill.

COVERINGS, UNDERGROUND, WOODEN
A. Wyckoff & Son Co., Elmira, N. Y.

CRANES
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

CRUSHING MACHINERY
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

CULVERTS
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron)
R. D. Wood Co., Philadelphia, Pa.

CYLINDER TRUCKS
Victor Equipment Co., 844 Folsom St., San Francisco, Calif.

DECHLORINATORS
Activated Alum Corp., 80 Broad St., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.

DIAPHRAGMS, PUMP
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

DIFFUSER PLATE HOLDERS
Aluminum Co. of America, Gulf Bldg., Pittsburgh, Pa.

DIFFUSERS—PLATES AND TUBES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Norton Co., Worcester, Mass.

DIGESTERS, SLUDGE
Dorr Co., 570 Lexington Ave., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

DISTRIBUTORS
Dorr Co., 570 Lexington Ave., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

DITCHERS AND TRENCHERS
Barber-Greene Co., Aurora, Ill.

DRAINS, STORM
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Lock Joint Pipe Co., Ampere, N. J.
R. D. Wood Co., Philadelphia, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.

DRIVES, CHAIN
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DRIVES, MULTI-V
Worthington Pump & Machy. Corp., Harrison, N. J.

DRY CHEMICAL FEEDERS
Fuller Co., Catasauqua, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Syntron Co., 400 N. Lexington St., Pittsburgh, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

DRYERS
Combustion Engrg. Co., 200 Madison Ave., New York City.
Decarie Incinerator Corp., 155 E. 44th St., New York City.
Koppers Rheolaveur Co., Pittsburgh, Pa.
Nichols Eng. and Research Corp., 40 Wall St., New York City.

DRYERS, ROTARY
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

DRYERS, SAND, PORTABLE
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

DRYERS—SPRAY
Bowen Research Corp., Garwood, N. J.

EDUCATORS
Vogt Mfg. Co., Louisville, Ky.

ELECTRO FERRO-CHOR PROCESS
Bowen Research Corp., Garwood, N. J.
Wallace & Tiernan Co., Inc., Newark, N. J.

ELECTROMETER
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment.)

ENGINES, DIESEL
Cooper-Bessemer Corp., Mt. Vernon, Ohio.
Fairbanks-Morse Co., 900 S. Wabash Ave., Chicago, Ill.
Worthington Pump Corp., Harrison, N. J.

ENGINES, GASOLINE
Novo Engine Co., Lansing, Mich.

ENGINES, SEWAGE SLUDGE GAS
Cooper-Bessemer Corp., Mt. Vernon, Ohio.
S. R. Dresser Mfg. Co., Bradford, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

EXCAVATORS, DITCH & TRENCH
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEEDERS, ROTARY
Fuller Co., Catasauqua, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

FENCE, STAINLESS STEEL
Pittsburgh Steel Co., Grant Bldg., Pittsburgh, Pa.

FENCING (IRON PICKET AND CHAIN LINK WIRE)
Pittsburgh Steel Co., Grant Bldg., Pittsburgh, Pa.
Stewart Iron Wks. Co., Cincinnati, Ohio.

FERRIC CHLORIDE, LIQUID AND ANHYDROUS
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Great Western Electro Chemical Co., 9 Main St., San Francisco, Calif.
Niagara Alkali Works, 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa. (Liquid)

FERRIC CHLORIDE FEEDERS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC SULFATE
Activated Alum Corp., 80 Broad St., New York City.
Merrimac Chemical Co., Boston, Mass.
Monsanto Chem. Co., St. Louis, Mo.

FERRIC SULPHATE FEEDERS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan, Inc., Newark, N. J.
Wilson Chem. Feeders, Inc., 110 Washington St., Buffalo, N. Y.

FERROUS SULPHATE
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.

FILTER-AIDS, CELITE
Johns-Manville, 22 E. 40th St., New York City.

FILTERING EQUIPMENT
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Filtration Equipment Co., 10 E. 40th St., New York City.
Filtration & Water Softening Pty., Ltd., Melbourne, Australia.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Sanitary Service, 155 E. 44th St., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Roberts Filter Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

FILTER PLATES
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

FILTERS, GRAVITY & PRESSURE
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER STRAINERS & NOZZLES
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Robert Filter Mfg. Co., Darby, Pa.

FILTERS, VACUUM
Filtration Equipment Corp., 10 E. 40th St., New York City.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.
Oliver United Filters Co., 33 W. 42nd St., New York City.

FILTER UNDERDRAINS
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Norton Co., Worcester, Mass.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Streamline Pipe and Fittings Div., Port Huron, Mich.

FITTINGS, UNDERGROUND SERVICE
American Brass Co., Waterbury, Conn.
Chase Brass & Copper Co., Inc., Waterbury, Conn.
S. R. Dresser Mfg. Co., Bradford, Pa.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Mueller Brass Co., Port Huron, Mich.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXERS
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Vogt Mfg. Co., Louisville, Ky.

FLOATING COVERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOCCULATING EQUIPMENT
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

FLOOR GRATING
Arrowhead Iron Wks., 421 W. 5th St., Kansas City, Mo.

FLOORING, INDUSTRIAL
Johns-Manville, 22 E. 40th St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
Wood Preserving Corp., Pittsburgh, Pa.

FLOOR STANDS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
R. D. Wood Co., Philadelphia, Pa.

FLOW RECORDERS
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

FLOW REGULATORS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
McNulty Engr. Co., So. Boston, Mass.
Modern Iron Works, Quincy, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FLUMES, IRON & STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D. St., So. Boston, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
R. D. Wood, Philadelphia, Pa.

FORMS & GASKETS FOR PIPE JOINTS
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FORMS, CONCRETE
Blaw-Knox Co., Pittsburgh, Pa.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products, Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.

GARBAGE DISPOSAL APPARATUS
Decarie Incinerator Corp., 155 E. 44th St., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Nichols Engr. & Research Corp., 40 Wall St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS DIFFUSERS
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Norton Co., Worcester, Mass.
Vogt Mfg. Co., Louisville, Ky.

GAS FIRED EQUIPMENT, RADIATORS, HEATERS, STORAGE HEATERS, AIR CONDITIONERS, ETC.
American Gas Prod. Corp., 40 W. 40th St., New York City.
Mueller Co., Decatur, Ill.

GAS HOLDERS
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS PRODUCERS, AUTOMATIC
Cooper-Bessemer Corp., Mount Vernon, Ohio.
Koppers Co., Pittsburgh, Pa.
R. D. Wood Co., Philadelphia, Pa.

GATES, DRAINAGE
Armco Culvert Mfrs. Assn., Middletown, Ohio.
McNulty Engrg. Co., 200 Old Colony Ave., Boston, Mass.

GATES, IRON PICKET & CHAIN LINK WIRE
Pittsburgh Steel Co., Grant Bldg., Pittsburgh, Pa.
Stewart Iron Wks. Co., Cincinnati, Ohio.

GATES, ROTARY DISCHARGE
Fuller Co., Catasauqua, Pa.

GATES, SHEAR
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.

GATES, SLUICE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Ludlow Valve Mfg. Co., Troy, N. Y.
McNulty Engrg. Co., 200 Old Colony Ave, Boston, Mass.

GATE VALVE HOUSING
Ludlow Valve Mfg. Co., Troy, N. Y.

GAUGES, LIQUID LEVEL, PRESSURE RECORDING
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelhia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

GENERATORS, ACETYLENE
Victor Equipment Co., 844 Folsom St., San Francisco, Calif.

GENERATORS, SETS, ELECTRIC & DIESEL ENGINES
Cooper-Bessemer Corp., Mt. Vernon, Ohio.
Fairbanks-Morse Co., 900 S. Wabash Ave., Chicago, Ill.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Worthington Pump Corp., Harrison, N. J.

GOOSENECKS
Mueller Brass Co., Streamline Pipe & Fittings Div., Port Huron, Mich.
Mueller Co., Decatur, Ill.

GRATINGS, FLOORINGS
Arrowhead Iron Wks., Kansas City, Mo.
Blaw-Knox Co., Pittsburgh, Pa.

GRAY IRON CASTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
So. Bend Foundry, So. Bend, Ind.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

GRINDERS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis,Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Norton Co., Worcester, Mass.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

GRINDING WHEELS
Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

GRIT CHAMBER EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

HAMMERS, CAULKING, CHIPPING
Hydraulic Development Corp., 50 Church St., New York City.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

HEATERS, FEED WATER
Worthington Pump & Machy. Corp., Harrison, N. J.

HOPPERS, STEEL
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

HOSE, RUBBER
Wallace & Tiernan Co., Inc., Newark, N. J.

HOSE, STEAM, AIR, WATER, SUCTION
American Brass Works, Waterbury, Conn.
Edson Corp., 49 D St., So. Boston, Mass.

HYDRANT PROTECTORS
Edson Corp., 49 D. St., So. Boston, Mass.

HYDRANTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Vogt Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

HYDRATED LIME
Limestone Prod. Corp. of Amer., Newton, N. J.

HYDRAULIC MACHINERY
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., Philadelphia, Pa.

HYDRAULIC TRANSFER SWITCHES
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.

HYDRAULIC VALVE CONTROLS
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. D. Wood Co., Philadelphia, Pa.

HYDROGEN ION EQUIPMENT
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Co., Baltimore, Md.
Permutit Co., 330 W. 42nd St., New York City.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.

HYPO-CHLORINATORS
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

INCINERATORS
Combustion Engr. Co., 200 Madison Ave., New York City.
Decarie Incinerator Corp., 155 E. 44th St., New York City.
Koppers Co., Pittsburgh, Pa.
Morse-Boulger Destructor Co., 205 E. 44th St., New York City.
Municipal Sanitary Service, 155 E. 44th St., New York City.
Nichols Engr., 40 Wall St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

INDICATORS, CHEMICAL
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.

INDICATOR POSTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
R. D. Wood Co., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.
Builders Iron Foundry, 9 Codding St., Providence, R. I.

INSTRUMENTS, FLOW RECORDING, TROUBLE FINDING
Brainard & Hatch, 246 Palm St., Hartford, Conn.

IRON & MANGANESE REMOVAL PLANTS
Graver Tank & Mfg. Co., East Chicago, Ind.
Intl. Filter Co., 59 E. Van Buren St., Chicago, Ill.

Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

IRON SALTS IN SEWAGE TREATMENT
Activated Alum Corp., 80 Broad St., New York City.
Gt. Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

IRON SULPHATE
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.

JACKS, MECHANICAL & SCREW
Edelblute Mfg. Co., Reynoldsville, Pa.
Templeton-Kenly & Co., 1020 S. Central Ave., Chicago, Ill.

JACKS, PULLING
Edelblute Mfg. Co., Reynoldsville, Pa.
Templeton-Kenly & Co., 1020 S. Central Ave., Chicago, Ill.

JOINTING COMPOUND
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Co., 50 Church St., New York City.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh (15), Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

JOINTS, EXPANSION—PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Johns-Manville, 22 E. 40th St., New York City.
Lock-Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Servicised Prod. Co., 6051 W. 65th St., Chicago, Ill.

JOINTS, FILLER
Inertol Co., 401 Broadway, New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

JOINTS, FLEXIBLE PIPE
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

JOINTS, MECHANICAL
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
McWane Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Weston's Gaskets & Forms, Adams, Mass.
R. D. Woods Co., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.
Tar and Chem. Div., Koppers Co., Pittsburgh, Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

LABORATORY APPARATUS
Carborundum Co., Niagara Falls, N. Y.
Corning Glass Works, Corning, N. Y.
Eimer & Amend, 18th & 3rd Ave., New York City.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Norton Co., Worcester, Mass.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Phipps & Bird, 915 E. Cary St., Richmond, Va.
Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan, Inc., Newark, N. J.

LABORATORY WARE
Carborundum Co., Niagara Falls, N. Y.
Corning Glass Works, Corning, N. Y.
Eimer & Amend, 18th and Third Ave., New York City.
La Motte Chem. Prod. Co., McCormick Bldg., Baltimore, Md.
Norton Co., Worcester, Mass.
Phipps & Bird, 915 E. Cary St., Richmond, Va.
Precision Scientific Co., 1750 N. Springfield Ave., Chicago, Ill.

LIME SLAKERS
Chicago Bridge & Iron Co., 37 W. Van Buren St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.

LINERS, ASPHALT SEWER
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

LOADERS, GRAVEL, WAGON, CAR, ETC.
Barber-Greene Co., Aurora, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

LUBRICATORS, FORCE FEED
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

MASTER METERS
Badger Meter Mfg. Co., Milwaukee, Wis.
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

METALS—CORROSION RESISTING
Amer. Brass Co., Waterbury, Conn.
Chase Brass & Copper Co., Inc., Waterbury, Conn.

METER ACCESSORIES, BOXES, HOUSING, ETC.
Badger Meter Co., Milwaukee, Wis.
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Ford Meter Box Co., Wabash, Ind.
Modern Iron Works, Quincy, Ill.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER-MASTER
Brainard & Hatch, 246 Palm St., Hartford, Conn.

METERS, GAS
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, PITOT
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METER TESTERS
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.

METER TESTING TANKS
Ford Meter Co., Wabash, Ind.

METERS, VENTURI
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METERS, WATER AND SEWAGE
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron & Foundry Co., Providence, R. I.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.
Union Water Meter Co., Worcester, Mass.
Worthington-Gamon Meter Co., Harrison, N. J.

MIXERS, CHEMICAL
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.

MIXING BASIN EQUIPMENT
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

NIPPLES, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Mueller Brass Co., Port Huron, Mich.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Pacific Flush Tank Co., 4241 N. Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

ODOR CONTROL
Activated Alum Corp., 80 Broad St., New York City.
Cloroben Corp., 90 Forest St., Jersey City, N. J.

OPERATING TABLES
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.

PACKING, RAWHIDE
Chicago Rawhide Mfg. Co., 1283 Elston Ave., Chicago, Ill.
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PAINT, ACID RESISTING
Atlas Mineral Prod. Co., Mertztown, Pa.
Barrett Co., 40 Rector St., New York City.
Ebony Paint Mfg. Co., 2925 E. 18th St., Kansas City, Mo.
General Paint Corp., Cleveland, Ohio
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh, Pa. (15)

PAVING ASPHALT BRIDGE PLANKS
Johns-Manville, 22 E. 40th St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

pH EQUIPMENT
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
La Motte Chem. Prod. Co., Baltimore, Md.
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan, Inc., Newark, N. J. (automatic)
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

PILING, CORRUGATED STEEL SHEET
Corrugated Steel Sheet Piling Corp., 228 N. La Salle St., Chicago, Ill.

PIPE, ALUMINUM
Aluminum Co. of America, Gulf Bldg., Pittsburgh, Pa.

PIPE AND TANK COATINGS
The Barrett Co., 40 Rector St., New York City.
Bartlett-Hayward Div., Koppers Co., Baltimore, Md.
Ebony Paint Mfg. Co., 2925 E. 18th St., Kansas City, Mo.
Inertol Co., Inc., 401 Broadway, New York City.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

PIPE, ACID PROOF, FOR CHEMICAL LINES
American Brass Works, Waterbury, Conn.
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Corning Glass Works, Corning, N. Y.
U. S. Pipe & Foundry Co., Burlington, N. J.
A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, ASBESTOS-CEMENT
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE, BRASS AND COPPER
American Brass Works, Waterbury, Conn.
Chase Brass Metal Co., Inc., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Streamline Pipe and Fittings Div., Port Huron, Mich

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
American Radiator Co., 40 W. 40th St., New York City.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Sonken-Galamba Corp., 64 N. Second St., Kansas City, Mo.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE, CAST IRON SERVICE, SMALL DIAMETER
American Cast Iron Pipe Co., Birmingham, Ala.
American Radiator Co., 40 W. 40th St., New York, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
McWane Cast Iron Pipe Co., Birmingham, Ala.

PIPE, COMMERCIAL O. D. WITH THREADED JOINTS
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
McWane Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, CONCRETE
Lockjoint Pipe Co., Ampere, N. J.

PIPE CONNECTIONS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
M. B. Skinner Co., South Bend, Ind.
R. D. Wood Co., Philadelphia, Pa.

PIPE, CORRUGATED
American Rolling Mill Co., Middletown, Ohio.
Armco Culvert Mfrs. Assn., Middletown, Ohio.

Mueller Brass Co., Streamline Pipe and Fittings Div., Port Huron, Mich.

PIPE ENAMELS, PROTECTIVE—COAL TAR

Barrett Co., 40 Rector St., New York City.
General Paint Corp., Cleveland, Ohio.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

PIPE FITTINGS

Aluminum Co. of America, Gulf Bldg., Pittsburgh, Pa.
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
McWane Cast Iron Pipe Co., Birmingham, Ala.
Mueller Brass Co., Streamline Pipe and Fittings Div., Port Huron, Mich.
Mueller Co., Decatur, Ill.
M. B. Skinner Co., South Bend, Ind.
Sonken-Galamba Corp., 64 N. Second St., Kansas City, Mo.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., Philadelphia, Pa.

PIPE, GLASS

Corning Glass Works, Corning, N.Y.

PIPE JOINT COMPOUNDS

Atlas Mineral Products, Mertztown, Pa.
The Barrett Co., 40 Rector St., New York City.
Hydraulic Development Co., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.
Modern Iron Works, Quincy, Ill.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Sauereisen Cements Co., Sharpsburg Station, Pittsburgh, Pa. (15)
Servicised Prod. Corp., 6051 W. 65th Ct., Chicago, Ill.

PIPE JOINT TOOLS

Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PIPE LINING MACHINE

T. A. Gillespie Co., 7 Dey St., New York City.

PIPE LOCATORS

Engineering Research Corp., 325 Giddens-Lane Bldg., Shreveport, La.
Water Leak Detector Co., 155 N. Third St., Columbus, Ohio.

PIPE PUSHERS

Templeton, Kenly & Co., 1020 S. Central Ave., Chicago, Ill.

PIPE RAILING

Aluminum Co. of America, Gulf Bldg., Pittsburgh, Pa.
Stewart Iron Works, Cincinnati, O.

PIPE, SEWER

American Cast Iron Pipe Co., Birmingham, Ala.
Armco Culvert Mfrs. Assn., Middletown, Ohio.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Lynchburg Foundry Co., Lynchburg, Va.
McWane Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
A. Wyckoff & Sons Co., Elmira, N. Y.

PIPE, STEEL

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.

PIPE TAPPING MACHINES

Mueller Co., Decatur, Ill.

PIPE, WELDED STEEL

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE WITH SPECIAL LININGS

American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
McWane Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, WOOD

A. Wyckoff & Son Co., Elmira, N. Y.

PIPE, WROUGHT IRON

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Reading Iron Co., Philadelphia, Pa.

PITOT TUBES

Builders Iron Foundry Co., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PLANTS, MUNICIPAL FILTRATION

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

PLUMBING SPECIALTIES

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Modern Iron Works, Quincy, Ill.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT

Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.

POROUS TUBES AND PLATES

Carborundum Co., Niagara Falls, N. Y.
Norton Co., Worcester, Mass.

POURING GATES

Hydraulic Development Corp., 50 Church St., New York City.

POWER TRANSMISSION MACHINERY

Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Reeves Pulley Co., Columbus, Ind.
Worthington Pump & Machy. Corp., Harrison, N. J.

PROPORTIONING EQUIPMENT

International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chem. Feeders, Inc., 110 Washington St., Buffalo, N. Y.

PROTECTION COURSE FOR WATERPROOFING

Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

PUMP PRIMERS

Automatic Primer Co., 113 W. Washington St., Chicago, Ill.
Barrett-Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

PUMPS, AIR LIFT

Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, BOILER FEED

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Corp., 3431 W. 48th Pl., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CELLAR DRAINER

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.

PUMPS, CENTRIFUGAL

Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Novo Engine Co., Lansing, Mich.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CENTRIFUGAL AND MULTI-STAGE HIGH LIFT

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Co., 3431 W. 48th Pl., Chicago, Ill.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CHEMICAL, PROPORTIONING

Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CIRCULATING

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, CONDENSATION

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, DEEP WELL

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, DIAPHRAGM

Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Novo Engine Co., Lansing, Mich.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.

PUMPS, HYDRANT

Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, NON-CLOG

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, ROTARY

Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SAND & GRAVEL

Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.

PUMPS, SCREW FEED CENTRIFUGAL

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SEWAGE

Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Novo Engine Co., Lansing, Mich.
Victor Equipment Co., 1010 E. 62nd St., Los Angeles, Calif.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SLUDGE

Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Fuller Co., Catasauqua, Pa.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Novo Engine Co., Lansing, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SUCTION AND FORCE

Edson Corp., 49 D St., South Boston, Mass.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, SUMP

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, TRIPLEX

Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, TURBINE

Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, VACUUM

Barrett-Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Eimer & Amend, 3rd Ave. and 18th St., New York City.
Fuller Co., Catasauqua, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUMPS, WATER SEAL

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

PUSH AND PULL JACKS

Edelblute Mfg. Co., Reynoldsville, Pa.
Templeton-Kenly & Co., 1020 S. Central Ave., Chicago, Ill.

RATE OF FLOW CONTROLLERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Builders Iron Foundry Co., Providence, R. I.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REAMERS

Mueller Co., Decatur, Ill.

RECARBONATORS

International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

RECEIVERS, AIR

Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.

RECUPERATOR

Carborundum Co., Perth Amboy, N. J.

REDUCTION MACHINERY

Jeffrey Manufacturing Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.
Norton Co., Worcester, Mass.

REFRACTORY CEMENTS

Carborundum Co., Niagara Falls, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Norton Co., Worcester, Mass.

REGULATORS, PRESSURE, ACETYLENE GAS

Union Water Meter Co., Worcester, Mass.
Victor Equipment Co., 840 Folsom St., San Francisco.

REGULATORS, SEWER

McNulty Engineering Co., 200 Old Colony Ave., South Boston, Mass.

REGULATORS, WATER AND GAS

Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

RESERVOIRS
(See Standpipes and Tanks)

ROBOT FILTER AND SOFTENER OPERATORS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

ROOFING
American Brass Works, Waterbury, Conn.
Johns-Manville, 22 E. 40th St., New York City.
Koppers Co., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.

RUBBER—ALL PURPOSES
United States Rubber Co., 1790 Broadway, New York City.

SADDLES, PIPE
S. R. Dresser Mfg. Co., Bradford, Pa.

SAMPLERS AND SAMPLING TABLES
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

SAND AND GRAVEL PLANTS
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher and Pulverizer Co., Dept. S, N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SAND FILTRATION
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

SANTOSITE
Monsanto Chemical Co., St. Louis, Mo.

SAWS—ELECTRIC, PORTABLE
Chain Belt Co., Milwaukee, Wis.
Syntron, 400 N. Lexington Ave., Pittsburgh, Pa.

SCREENS, INTAKE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Lakeside Engr. Corp., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SAND, GRAVEL AND STONE
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Municipal Sanitary Service, 155 E. 44th St., New York City.

SCREENS, SEWAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engineering Co., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Sanitary Service, 155 E. 44th St., New York City.

SCREENS, WATER WELL
Layne & Bowler, Inc., Memphis, Tenn.

SELF-CAULKING PIPE JOINT COMPOUNDS
Atlas Mineral Prod., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

SEWAGE CLEANING BALLS, RUBBER
W. J. Voit Rubber Corp., P. O. Box 250, Arcade Station, Los Angeles, Calif.

SEWAGE EJECTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

SEWAGE SAMPLERS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

SEWAGE SCREENING GRINDERS
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Boyer Foundry & Mach. Co., Kingston, Pa.

SEWAGE SLUDGE INCINERATOR
Municipal Sanitary Corp., 155 E. 44th St., New York City.
Nichols Engineering & Research Corp., 40 Wall St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

SEWAGE TREATMENT EQUIPMENT
American Centrifugal Corp., 115 Broadway, New York City.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lancaster Iron Works, 122 E. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SEWER MAIN CLEANERS
Champion Corp., Hammond, Ind.
National Water Main Cleaning Co., 50 Church St., New York City.

SEWER PIPE JOINTS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
L. A. Weston, Adams, Mass.

SEWER RODS
Champion Corp., Hammond, Ind.

SIGHT GLASSES
Corning Glass Works, Corning, N. Y. (Pyrex Brand)

SIGNALS, BIN
Fuller Co., Catasauqua, Pa.

SIPHONS
Modern Iron Works, Quincy, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SLEEVES, PIPE REPAIR
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
S. R. Dresser Mfg. Co., Bradford, Pa.
McWane Cast Iron Pipe Co., Birmingham, Ala.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (VALVE)
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Vogt Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SLUDGE DEWATERING
American Centrifugal Corp., 115 Broadway, New York City.
Bowen Research Corp., Garwood, N. J.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.

SLUDGE DISINTEGRATORS
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE FILTERS
Filtration Equipment Corp., 10 E. 40th St., New York City.
Municipal Sanitary Service Corp., 155 E. 44th St., New York City.
Oliver United Filters Co., 33 W. 42nd St., New York City.

SLUDGE PUMPS
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Novo Engine Co., Lansing, Mich.

SLUDGE TESTING (pH AND CHLORINE)
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., McCormick Bldg., Baltimore, Md.
W. A. Taylor & Co., Inc., 872 Linden Ave., Baltimore, Md.
Worthington Pump & Machy. Corp., Harrison, N. J.

SODA ASH
The Columbia Alkali Corp., Barberton, Ohio.
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Niagara Alkali Works, 9 E. 41st St., New York City.
Penn. Salt. Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM ALUMINATE
Merrimac Chemical Co., Boston, Mass.
National Aluminate Corp., 6216 W. 6th Pl., Chicago, Ill.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM HYPOCHLORITE
The Columbia Alkali Corp., Barberton, Ohio.
Electro Bleaching Gas Co., 9 E. 41st St., New York City.
Great Western Electro-Chemical Co., 9 Main St., San Francisco, Calif.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Merrimac Chemical Co., Boston, Mass.
Niagara Alkali Works, 9 E. 41st St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SPEED REDUCERS, TRANSMISSION
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Reeves Pulley Co., Columbus, Ind.

SPRAY DRYING EQUIPMENT
Bowen Research Corp., Garwood, N. J.

SPRINKLING FILTER PLANTS
Dorr Co., 570 Lexington Ave., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

STACKS, FUME
Johns-Manville, 22 E. 40th St., New York City.
A. Wyckoff & Son, Elmira, N. J.

STANDPIPE AND TANKS
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Columbia Steel Tank Co., Kansas City, Mo.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STEAM AND GAS PURIFIERS
Carborundum Co., Niagara Falls, N. Y.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.

STEEL PLATE CONSTRUCTION
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STIRRERS
Dorr Co., 570 Lexington Ave., New York City.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

STOKERS
Combustion Engineering Co., 200 Madison Ave., New York City.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.

STRAINERS, SUCTION
Barrett-Haentjens & Co., Hazleton, Pa.
Edson Corp., 49 D St., South Boston, Mass.

SULPHATE OF ALUMINA
Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

SWIMMING POOL EXPANSION JOINTS
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

SWIMMING POOLS AND EQUIPMENT
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SWIMMING POOL CHEMICALS
Activated Alum Corp., 80 Broad St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Wallace & Tiernan, Co., Inc., Newark, N. J.

SWIMMING POOL PAINT IN COLORS
Inertol Co., Inc., 401 Broadway, New York City.

SWIMMING POOL TESTING OUTFITS (pH and Chlorine)
LaMotte Chem. Prod. Co., Baltimore, Md.
Phipps and Bird, 915 E. Cary St., Richmond, Va.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.

SWITCHES, FLOAT
Barrett-Haentjens & Co., Hazleton, Pa.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

TAMPERS, TRENCH
Modern Iron Works, Quincy, Ill.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

TANKS, ELEVATED STEEL
Chicago Bridge & Iron Company 2198 Old Colony Bldg., Chicago, Ill.
R. D. Cole Co., Newnan, Ga.
Columbia Steel Tank Co., Kansas City, Mo.
Graver Tank & Mfg. Co., East Chicago, Ind.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANKS, RUBBER LINED
Wallace & Tiernan Co., Inc., Newark, N. J.

TANKS, SEDIMENTATION
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., East Chicago, Ind.
Lancaster Iron Wks., 122 E. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANKS, SEPTIC
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lancaster Iron Works, Inc., 122 E. 42nd St., New York City.

TANKS, STEEL
(See Tanks, Elevated Steel)

TASTE & ODOR REMOVAL CHEMICALS
Activated Alum Corp., 80 Broad St., New York City.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Industrial Chemical Sales Co., Inc., 230 Park Ave., New York City.
L. A. Salomon & Bros., 216 Pearl St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.

TASTE AND ODOR REMOVAL EQUIPMENT
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

TESTERS, WATER METER
Ford Meter Box Co., Wabash, Ind.

THICKENERS
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.

TORCHES; WELDING & CUTTING; BRAZING & SOLDERING
Victor Equipment Co., 840 Folsom St., San Francisco, Calif.

TREADS, SAFETY
Arrowhead Iron Works, Kansas City, Mo.
Blaw-Knox Co., Pittsburgh, Pa.

TRENCH BRACES
(See Braces, Trench Excavating)

TURBIDITY TESTERS
Hellige, Inc., 3719 Northern Blvd., Long Island City, N. Y.

TURBINES, HYDRAULIC
S. Morgan Smith Co., York, Pa.

VACUUM HEATING PUMPS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

VALVE BOXES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Modern Iron Works, Quincy, Ill.
Vogt Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVE OPERATING PARTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
R. D. Wood Co., Philadelphia, Pa.

VALVES
American Brass Works, Waterbury, Conn.
Automatic Primer Co., 113 W. Washington St., Chicago, Ill.
Barrett-Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fitting Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., Philadelphia, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

VALVES, ALTITUDE
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Union Water Meter Co., Worcester, Mass.

VALVES, CHECK
Barrett-Haentjens & Co., Hazleton, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CONE, OF ALL TYPES
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, EMERGENCY TRIP
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

VALVES, ENGINE STOP AND THROTTLE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

VALVES, FLAP
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FLOAT
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.

VALVES, FOOT
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Ludlow Valve Mfg. Co., Troy, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FOUR WAY
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.

VALVES, GATE
American Brass Works, Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Bartlett-Hayward Div., Koppers Co., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Vogt Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

VALVES, HYDRAULIC CYLINDER OPERATED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Western Gas Div., Koppers Co., Fort Wayne, Ind.
Ludlow Valve Mfg. Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MOTOR OPERATED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Western Gas Div., Koppers Co., Ft. Wayne, Ind.
Ludlow Valve Mfg. Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MUD AND PLUG
Barrett-Haentjens & Co., Hazleton, Pa. (plug).
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, RUBBER, GLASS AND LEAD LINED
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.

VALVES, SPECIAL AUTOMATIC
Crane Co., 836 S. Michigan Ave., Chicago, Ill
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, STANDPIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

VALVES, TRIPLE ACTING NON-RETURN
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

VALVES, UNLOADING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

VALVES, WATER & STEAM REDUCING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
S. Morgan Smith, York, Pa.

VALVES, WATER METER SPECIAL
Ford Meter Box Co., Wabash, Ind.

VALVES, WATER RELIEF
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, WATER SERVICE—HAND OPERATED & POWER OPERATED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Ludlow Valve Mfg. Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VENTURI TUBES
Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

VIBRATORS
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

WASHING MACHINERY, SAND AND GRAVEL
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

WASTE GAS BURNERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

WASTE (INDUSTRIAL) TREATMENT
Activated Alum Corp., 80 Broad St., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lancaster Iron Wks., 122 E. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

WATER ANALYSIS EQUIPMENT AND REAGENTS
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
La Motte Chem. Prod. Co., Baltimore, Md.
W. A. Taylor & Co., 872 Linden Ave., Baltimore, Md.
Wallace & Tiernan Co., Inc., Newark, N. J.

WATER LEAK, LOCATING INSTRUMENTS
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Water Leak Detector Co., 155 N. Third St., Columbus, Ohio.

WATER LEVEL RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER MAIN CLEANING
Champion Corp., Hammond, Ind.
National Water Main Cleaning Co., 50 Church St., New York City.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS
Ebony Paint Mfg. Co., 2925 E. 18th St., Kansas City, Mo.
General Paint Corp., Cleveland, Ohio.
Inertol Co., Inc., 401 Broadway, New York City.
Johns-Manville, 22 E. 40th St., New York City.
Reilly Tar & Chem Co., Merchants Bank Bldg., Indianapolis, Ind.
Sika, Inc., 1943 Grand Central Terminal, New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

WATER PURIFICATION EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

WATER RECORDING INSTRUMENTS, MEASURING EQUIPMENT
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Brainard & Hatch, 246 Palm St., Hartford, Conn.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

WATER SEAL PUMPING UNITS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

WATER SOFTENERS
International Filter Co., 59 E. Van Buren St., Chicago (lime-soda).
National Aluminate Corp., 6216 W. 66th Pl., Chicago, Ill.
Permutit, Inc., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Co., Darby, Pa.

WATER SUPPLY SYSTEMS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Fairbanks, Morse & Co., 900 S. Wabash Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Modern Iron Works, Quincy, Ill.
Worthington Pump & Machy. Corp., Harrison, N. J.

WEATHERPROOF PAINTS, ROOF COATINGS
Ebony Paint Mfg. Co., 2925 E. 18th St., Kansas City, Mo.
General Paint Corp., Cleveland, Ohio.
Inertol Co., 401 Broadway, New York City.
Johns-Manville, 22 E. 40th St., New York City.
Tar & Chem. Div., Koppers Co., Pittsburgh, Pa.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

WEIGHERS, AUTOMATIC BATCH
Fuller Co., Catasauqua, Pa.
Jeffrey Mfg. Co., Columbus, Ohio.

WEIGH FEEDER MACHINES
Jeffrey Mfg. Co., Columbus, Ohio.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Syntron Co., 400 N. Lexington Ave., Pittsburgh, Pa.

WINDOW GUARDS
Stewart Iron Works, Cincinnati, Ohio.

WIRE, CARBON & STAINLESS STEEL
Pittsburgh Steel Co., Grant Bldg., Pittsburgh, Pa.

WIRE MESH PARTITIONS
Stewart Iron Works, Cincinnati, Ohio.

ZEOLITE MINERALS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

ZEOLITE WATER SOFTENERS
Graver Tank & Mfg. Co., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS*—WHERE TO FIND IT

By L. H. ENSLOW
Editor WATER WORKS AND SEWERAGE

The subject which has been assigned me is of a rather large order and will be dealt with only in part. I will content myself with stating where information of various sorts may be found.

It goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manual published by the American Water Works Association—"Water Works Practice."

Regardless of the availability of published information, reference books, etc., it is well known that practical experience is essential in solving most water and sewage problems.

Reference Works. Text books, manuals, hand-books, journals, and catalogs are named in the attached list of recommended reference work for water sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists. I was somewhat reticent about taking the sole responsibility of naming such a list and therefore called on men fully qualified to offer suggestions to make up a set of reference works.

I had not thought of catalogs put out by manufacturers as being of value beyond use in specifying and purchasing materials and equipment, but one of my collaborators who is Superintendent of Operations of a company operating a large number of plants states the following:

"I find that in my own work the most frequently consulted books are the catalogs of the manufacturers of water works materials and equipment. These catalogs are of constant use, not only in connection with the purchasing of the goods listed, but also due to the vast amount of information contained in them as to the available styles, weights, dimension, capacities, and many other features."

Small Works and Large Works. It had been my thought that I might make up a list of reference works which would cover the needs of managers and operators of small and medium sized works and another which would be more extensive for the larger works. A superintendent of a small works writes as follows, and I am forced to agree with him to a major degree.

"In my opinion, the small town superintendent should have just as complete knowledge of fundamentals as the large town superintendent and in fact would have problems coming to his personal attention which might require more detailed knowledge than would be the case with the superintendent of a large system who would delegate such work to various assistants."

Current Information. Current information is best obtained through the technical journals, trade papers, manufacturers' publications.

Attending meetings, listening to papers read and discussion of these, is of paramount value. Demonstrations such as those put on during meetings are extremely valuable and operations of this nature can not, as a rule, be found described in books. Operating papers in the journals and trade publications, however, frequently describe "operating kinks" of a great value.

Reprints and Bulletins. Manufacturers and Trade Associations frequently distribute information of value in the nature of reprinted articles, house-organs or bulletins. Ofttimes these are mailed out only upon request, or by sending in a coupon incorporated in an advertisement. It therefore pays to read the ads.

Such publications usually contain valuable information and often serve a very useful purpose. If they are not bulky these may be filed away or placed in a loose leaf binder under the heading of the subject matter, as for example, "Meters and Meter Maintenance," "Tanks and Standpipes," "Water Treatment," "Algae Control," etc., etc. If bulky, they may be torn apart and the most valuable parts filed for future reference. It is surprising how much worthwhile information and data can thus be accumulated in a readily available form and at practically no cost. Some men make a practice of tearing apart technical magazines and filing the desired contents under subject matter heading where the information will be more readily available thereafter.

Filing Schemes. I have found the following filing schemes practical, serviceable and inexpensive:

For the office, the old fashioned and inexpensive box letter-file, made of cardboard and wood, is very useful. The index is removed and the clippings, reprints, etc., covering a single "subject-head" are placed in envelopes or folders properly labeled and preserved in the box files. These boxes are properly labeled to show their subject matter contents and stored on end on a shelf as one would store a set of books. As the contents of a single box grows it may be necessary later to devote an entire box to a single subject head. "Water Treatment" for example will probably require a single box which may contain a folder on water softening, and others on coagulation, aeration, corrosion control, etc. One subject head can be broken down into as many sub-divisions as may appear desirable. I have one which contains 16 sub-divisions and this assists in prompt location of the desired information when needed.

Some people may prefer to use metal box files of the same size which are also available, but more expensive. Others may prefer a set of loose leaf binders, but I find the boxes are simpler, offer more protection to the filed sheets and keep the dust out.

Information such as conversion factors, data tables and formulae which are more frequently used may best be filed in a pocket-size loose leaf book. The paper can be reinforced with little gummed linen eyelets where the rings pass through and the sheet folded if need be to fit into the binder or it may be cut into parts and glued at its corners to both sides of a filler sheet of the binder. An index in the binder serves a useful purpose in that it facilitates location of the desired tables of data or conversion figures. For work in the field the pocket size loose-leaf book is almost indispensable. I have one fairly well filled with curves and data cut from magazines, journals, and booklets distributed by manufacturers.

Short Courses for Superintendents and Operators. This scheme has been followed successfully in many states. The courses are so arranged that those taking it are not in the least embarrassed by any lack of prior education. Much of the course is of a practical nature and the chemistry and biology lectures and laboratory work are made simple and attractive. Superintendents who have attended these schools have found them very helpful and have returned to take the courses another year, which is an excellent indication of their usefulness. Materials men, factory representatives, sales engineers and other specialists are called upon to give demonstrations of important equipment used in water works systems. All of this is very useful and helpful to the manufacturer as well as the "students." Questions are freely asked and answered.

I do not hesitate to recommend the Short Course to every one of you and I believe that you will find the slight expense and the time spent a thoroughly good investment.

Special and Unusual Problems. When a special or an unusual problem presents itself to water works or sewage works operators, information required may not be easily found in published form. In such instances the State Health Department personnel can be of material help and I can assure you, as a former operator and later affiliated with two State Departments of Health, that the engineers and chemists connected with the Department are always glad to assist the operator or the management of a public works wherever they can. Call freely on your Health Department Engineer for information and advice and you will be the gainer.

In instances, the problem will be of a nature that can be solved by utilizing information obtainable through the Research

*A paper presented before the Southeastern Section, American Water Works Association in 1932. Revised in 1937.

and Development Departments of manufacturers, Institutes, or Trade Associations. In my capacity of Research Engineer of the Chlorine Institute I have frequently been able to supply special information covering problems in chlorine application which, of nature, I was better prepared to give than someone else because of my long and intimate contact with chlorinating problems. Other associations are equipped to give similar service in connection with their products.

I have not understood why consulting engineers and chemists are not more regularly approached for advice and information covering special problems. I believe that managers of water and sewage systems overlook the value of having their municipality retain consultants on an annual fee basis in order to be in a position to seek advice as frequently as need be by mail or 'phone. This is practiced by some cities but as a rule the small municipalities, which would profit relatively more perhaps than the larger cities by such an arrangement, fail to take advantage of this relatively low cost service. Consultants are not prone to charge small municipalities as heavy as they would those more able to pay. Industry finds that it pays to retain consultants on an annual fee basis and it sems that municipalities should find the same.

I believe that every home should have its family physician and that every municipality needs the services of a consulting engineer to prescribe "remedies" over the 'phone just as the family physician does and thus frequently saves the patient much discomfort or prevents the necessity of a "major operation" later.

I find an increasing tendency on the part of small towns to retain chemists and engineers to supervise plant operations and at the same time supply advice and information whenever required. If engineers and chemists were as good salesmen as are lawyers and physicians, more of this kind of valuable service would be made use of.

Visiting. An excellent means of procuring information covering operation and maintenance is by visiting water and sewage works plants. Many of us are prone to inspect the works of our neighbors with a critical eye. We see too easily the weak points. If, on the other hand, we should look around and make inquiries in a less critical frame of mind, or with an attitude of seeking all possible information, more of value could be learned.

When one attends a water or sewage works meeting or a short course he is actually "visiting" because there he meets and tasks with men from other places. That is next in value to an actual visit or first hand inspection of the other fellow's works. I wish to stress the importance of visiting and exchanging experiences.

Acknowledgment. I acknowledge, with appreciation, the assistance of the several men who contributed suggestions of reference books, catalogs, etc., which proved helpful in preparing the following lists:

Note—Our list of 1936 contained several out-of-print publications. The following is a revised and enlarged listings.

LIST NO. 1*—FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
Water Works Practice—Manual of the A. W. W. A.	Williams & Wilkins, Baltimore	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Water Supply Control	N. Y. State Dept. Health, Albany, N. Y.	
Water Works Handbook	McGraw-Hill Co., New York City	Flynn, Weston & Bogert
Water Purification Control, 2nd Edition	Williams & Wilkins, Baltimore, Md.	Hopkins
Standard Methods of Water Analysis	A. P. H. A., New York City	
Lab. Manual—Chemical & Bacterial Analysis Water and Sewage, 2nd Edition	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Water Purification	McGraw Hill Co., New York City	Ellems
Copper Sulphate in Control of Micro Organisms (F)	Nichols Copper Co., New York City	Hale
Pump Data (F)	Economy Pumping Mach. Co., Chicago	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa.	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
†Chlorination of Water	John Wiley & Sons, New York City	Race
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J	Various
Reprints of Articles on Chlorine and Its Application	The Chlorine Institute, New York City	Various
Hydraulic Tables	John Wiley & Sons, New York City	Williams & Hazen
Cameron Hydraulic Data (F)	Ingersoll-Rand, Phillipsburgh, N. J.	
Handbook on Fire Protection	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Fire Engine Tests and Fire Stream Tables	National Board of Fire Underwriters, N. Y. C.	
Plumber's Handbook	McGraw-Hill Co., New York City	Dibble
Examination of Water	John Wiley & Sons, New York City	Mason & Buswell
Public Water Supplies	John Wiley & Sons, New York City	Turneau & Russell
American Civil Engineering Handbook	John Wiley & Sons, New York City	Merriman & Wiggin
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Water Supply & Treatment	National Lime Assn., Washington, D. C.	Hoover
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md.	
Modern P. H. Control (F)	W. A. Taylor Co., Baltimore, Md.	
"Hydro-tite" Booklet of Useful Information (F)	Hydraulic Development Corp., New York, N. Y.	
Water Supply Engineering	McGraw-Hill Co., New York City	Babbitt & Dorland
Microscopy of Drinking Water	John Wiley & Sons, New York City	Whipple
Plane Surveying	John Wiley & Sons, New York City	Tracey

(F) Available as Free Publication at this writing, May, 1937.
*Revised and enlarged, May, 1937.
†Needs revision badly; but is best book of its kind now available.

Journals and Magazines (Applies to Lists 1 and 2)

Journal and Monographs of the American Waterworks Association.
Journal of the New England Water Works Association.
Current Water Works Technical Magazines.

LIST NO. 2*—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1 for smaller works)

Books	*Publishers*	*Authors*
Fresh Water Biology	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae	McGraw-Hill Co., New York City	Smith
Elements of Water Bacteriology	John Wiley & Sons, New York City	Prescott & Winslow
"Industrial Water Supplies"	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk

The Determinations of H. Ions	John Wiley & Sons, New York City	Whipple, Fair & Whipple
pH and Its Practical Application	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Microscopy of Drinking Water	John Wiley & Sons, New York City	Whipple, Fair & Whipple
Elimination of Tastes and Odors in Water	McGraw-Hill Co., New York City	Baylis
Boiler Feedwater Purification	McGraw-Hill Co., New York City	Powell
Chemistry of Water and Sewage Treatment	Chemical Catalog Company, New York City	Buswell
Water Borne Typhoid Fever Outbreaks	Williams & Wilkins Co., Baltimore, Md.	Wolman & Gorman
Textbook of Bacteriology	Appleton & Co., New York City	Hiss & Zinsser
Corrosion; Causes and Prevention	McGraw-Hill Co., New York City	Speller
Water Supply Paper No. 658 (Quality of Waters)	U. S. Geological Survey, Washington, D. C.	Stabler
Water Supply Engineering	McGraw-Hill Co., New York City	Babbitt & Doland
Handbook of Hydraulics	McGraw-Hill Co., New York City	King
Concrete Engineers' Handbook	McGraw-Hill Co., New York City	Hool & Johnson
Pocket Companion	Carnegie Steel Corp., New York City	
Business Law for Engineers	McGraw-Hill Co., New York City	Allen
Mechanical Engineers' Handbook	John Wiley & Sons, New York City	Kent
Elements of Hydraulics	John Wiley & Sons, New York City	Merriman
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Theory and Practice of Public Utility Valuation	McGraw-Hill Company, New York City	Maltbie
Public Utility Rates	McGraw-Hill Co., New York City	Barker
Census of Munic. Water Purification Plants	Am. Water Works Assn., New York City	

(F) Available as Free Publication at this writing, May, 1937.
*Revised and enlarged, May, 1937.

For Journals see list No. 1.

LIST NO. 3*—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS

Books	*Publishers*	*Authors*
Operation and Control of Sewage Treatment Plants	New York State Dept. Health	N. Y. State Dept. Health
Arithmetic of Sewage Disposal	John Wiley & Sons, New York City	Imhoff & Fair
Sewerage and Sewage Disposal (A Text Book)	McGraw-Hill Co., New York City	Metcalf & Eddy
Chemical Analysis of Water and Sewage (with explanatory sections)	Edwards Brothers, Ann Arbor, Mich.	Eldridge & Theroux
Bulletins Nos. 59, 68, 69, 84 and 86 (F)	Iowa State College, Ames, Iowa	Various
Manual of Sewage Works Operation	New Jersey Sewage Expt. Sta., New Brunswick, N. J.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J., and The Chlorine Inst. N. Y. C.	
Chlorination in Sewage Treatment (F)	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Chemical Treatment of Sewage	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Standard Methods of Water and Sewage Analysis	Amer. Pub. Health Assn., N. Y. C.	
Laboratory Manual of Water and Sewage Analysis	McGraw Hill Co., New York City	Theroux, Eldridge & Mallman

*Revised and enlarged, May, 1937.

LIST NO. 4*—FOR MANAGER, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS

(In addition to List No. 3 for smaller works)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition)	McGraw-Hill Co., New York City	Metcalf & Eddy
Solving Sewage Problems	McGraw-Hill Co., New York City	Fuller & McClintock
Sewerage and Sewage Treatment	John Wiley & Sons, New York City	Babbitt
Sewage Disposal	McGraw-Hill Co., New York City	Fuller
The Chemistry of Water and Sewage Treatment	Chemical Catalog Co., New York	Buswell
The Hoover Plumbing Code (B.H.13)	U. S. Bureau of Standards	
Sewerage and Sewage Treatment	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewage Disposal**	John Wiley and Sons, New York City	Kinnicutt, Winslow & Pratt
Sewage Works Journal—(Official publication of the Federation of Sewage Wks. Assns.)		
Current Sewerage Magazines		

*Revised and enlarged, May, 1937.
(F) Available as Free Publication at this writing, May, 1937.
**A very old book, but one easy to use as a quick reference to standard practices of the past and a discussion of fundamentals.

Journals and Magazines (Applies to Lists 3 and 4)

Note:—Sewerage men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books of pipe and pump data.

WATER

A Discussion of Flows, Friction, Measurement and Power*

The rate of flow or the volume of water passing a cross section of a stream in a unit time is called the "discharge." If a uniform velocity at all points in the cross section of a stream were possible, there would be passing any cross section of the stream, every unit of time, a prism of water having a base equal to the cross-sectional area of the stream and a length equal to the velocity. However, due to the varying effects of friction and viscosity, the different filaments of water move with different velocities. For this reason it is common in hydraulics to deal with "mean velocities."

The discharge may be expressed in terms of the mean velocity:

$$Q = av$$

where Q = Discharge in cubic feet per second.
a = Cross-sectional area of stream in square feet.
v = Mean velocity in feet per second.

When the discharge is constant (i.e., when the same quantity of water passes any cross section of a stream during equal successive intervals of time) the flow is said to be "steady."

Flow is said to be "uniform" when there is little or no change in the cross section or velocity from point to point in a stream. Thus uniform flow implies similarity of conditions at successive cross sections at any given instant, while steady flow involves permanency of conditions at any particular cross section.

In hydraulics the term "pressure head," "static head" or simply "head" is used to designate the vertical height of a static column of liquid which, due to its weight, would produce a pressure equivalent to the pressure in the fluid at the point in question.

The "velocity head" is the height through which a body must fall in a vacuum to acquire the velocity with which water flows in a stream. The velocity head corresponding to any velocity is equal to the static head, which (neglecting friction) could cause (or could be caused by) that velocity. The relation between velocity head and velocity may be expressed by the formula:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Flow of Water Through Orifices and Tubes

As commonly used in hydraulics, the term orifice is used to designate an opening with a closed perimeter, and of regular shape, through which water flows. If the perimeter is not closed, or if the opening flows only partially full, the orifice becomes a weir.

An orifice with prolonged sides, such as a short piece of pipe two or three diameters in length, set in the side of a reservoir, is called a tube. An orifice in a thick wall has the hydraulic properties of a tube.

The theoretical velocity of a stream or jet of water issuing from an orifice is given by the formula:

$$v_t = \sqrt{2gh}$$

where v_t = Theoretical velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.
h = Head on the center of the orifice in feet.

The actual velocity of the jet is less than the theoretical velocity because of the frictional loss which occurs as the water approaches the orifice. The ratio of the actual mean velocity, v, to the theoretical velocity, v_t, is called the "velocity coefficient" and is designated by the symbol C_v. The actual mean velocity of the jet is therefore:

$$v = C_v\sqrt{2gh}$$

The stream or jet issuing from an orifice is not in all cases the same size as the opening of the orifice because of contraction effects in certain cases and flaring effects in other cases. The "contraction coefficient," C_c, of an orifice is the ratio of the cross-sectional area of the jet to that of the orifice.

The discharge from an orifice is given by the formula:

$$Q = C_vC_ca\sqrt{2gh}$$

where Q = Discharge in cubic feet per second.
a = Area of orifice opening in square feet.

It is customary to combine the coefficients C_v and C_c into a single coefficient C_d which is called a "discharge coefficient." The discharge coefficient is therefore a product of the velocity coefficient and the contraction coefficient, or $C_d = C_v \times C_c$.

The formula for discharge from an orifice then becomes:

$$Q = C_da\sqrt{2gh}$$

Table 12 gives average values of discharge coefficients for various types of orifices and tubes.

Flow of Water in Pipe and Open Channels

As the term is used in hydraulics, a pipe may be defined as a closed conduit which flows full under pressure. By open channel is meant any kind of water course with the top surface of the flowing water exposed to the atmosphere, such as a canal, aqueduct, flume, sewer or river.

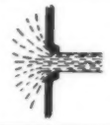
The "wetted perimeter" of any conduit is that portion of the perimeter of the cross section of the conduit in contact with the liquid.

The "hydraulic radius" of a conduit is the cross-sectional area of the stream, divided by the wetted perimeter of that section. For a circular pipe flowing either full or half full the hydraulic radius is one-fourth the pipe diameter (or one-half the pipe radius).

If a tube is tapped into the wall of a vessel or pipe containing water under pressure, the water will rise in the tube to a height equal to the head producing the pressure at the point where the tube is inserted. Such a tube is called a "piezometer" tube. Piezometer tubes measure pressure above atmospheric pressure (gage pressure) since the water surface in the tube is subjected to atmospheric pressure. When piezometer tubes are used to measure pressure heads in pipes where water is in mo-

Table 12

Discharge Coefficients for Various Types of Orifices and Tubes

Diagram	Description	Average discharge coefficient, C_d
	SHARP-EDGED ORIFICE The stream is contracted to about 0.62 of the area of the opening.	0.61
	**ORIFICE WITH WELL-ROUNDED ENTRY** There is little or no contraction and the stream is about the same size as the opening.	0.98
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When flowing full. When the length of the tube is 2½ diameters it is called a "standard short tube".	0.82
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When the stream springs clear from the tube at the upstream corner the flow is the same as for a sharp-edged orifice.	0.61
	RE-ENTRANT TUBE Length about 2½ diameters. Flowing full.	0.73
	RE-ENTRANT TUBE When the length is about one diameter it is called "Borda's Mouthpiece". Stream springs clear of the walls of the tube.	0.52

*The material under this heading has been drawn from Technical Bulletin No. 21, recently issued by National Tube Co. of Pittsburgh, Pa.—Ed.

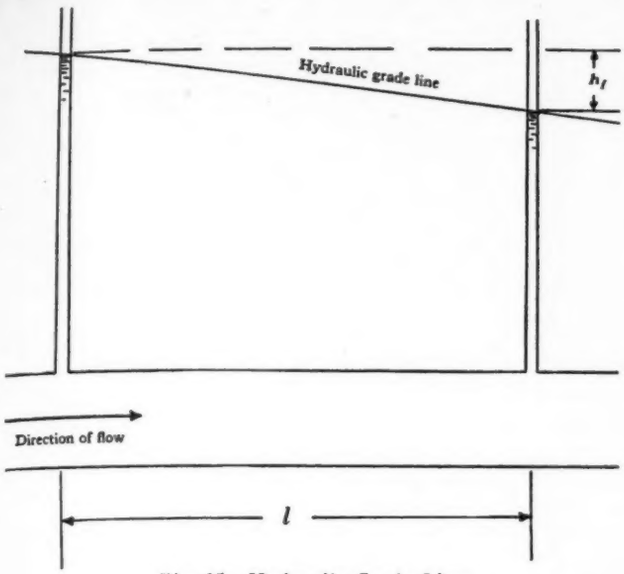


Fig. 35—Hydraulic Grade Line

tion, the end of the tube should enter the pipe at right angles to the direction of flow and the end of the tube should be flush with the inner surface of the pipe.

If a pipe full of water is provided with several piezometer tubes, a line joining the tops of the columns of water in the tubes is called the "hydraulic grade line," and the slope of this line is the "hydraulic slope" or simply the "slope." Two piezometer tubes attached to a pipe line are shown in Fig. 35. The line joining the tops of the columns of water in the tubes represents the hydraulic grade line and h_f represents the loss of head in length l. The hydraulic slope, s, is therefore:

$$s = \frac{h_f}{l}.$$

Friction

There is always friction between moving water and the surface with which the water comes into contact. There is also friction between the moving particles of the water themselves which is commonly called viscosity.

Water particles in contact with the conduit surface are retarded by friction, and viscosity causes a retardation of the particles removed from the conduit surface. Therefore, water flowing in a pipe has its maximum velocity at the center and its minimum velocity near the pipe walls.

If there were no friction losses, the theoretical velocity, v_t, at which water would discharge from a pipe or channel would be $v_t = \sqrt{2gh}$. In any long pipe or channel, however, the greater portion of the total head is used in overcoming friction.

The amount of frictional resistance offered by any surface increases with the degree of roughness of the surface. The resistance due to viscosity decreases as the temperature of the water increases.

The loss of head due to the combined effects of viscosity and friction between the moving water and the surface of the conduit is usually referred to as the loss of head due to friction.

The influences of friction and viscosity on the flow of water have been determined experimentally by various authorities and a variety of formulas for the loss of head due to friction have been derived. Only a few of the best-known and most generally used formulas will be presented in this article.

In addition to the loss of head due to friction, other losses of head result from changing the velocity or direction of flow. These special losses are considered in Table 21.

Formulas for Flow of Water In Pipe and Open Channels

The Chezy Formula

The most generally used formula for determining the velocity of flow of water in pipe and open channels is the Chezy Formula:

$$v = c\sqrt{rs}, \text{ or } v = cr^{0.5}s^{0.5}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = A coefficient which Chezy considered to be constant, but which is now known to vary with the hydraulic slope and hydraulic radius as well as with the degree of roughness of the surface with which the water comes in contact.

This formula, although originally designed for open channels, is with proper modification applicable to either open channels or pipe.

The Hazen-Williams Formula

For the same degree of roughness, the value of c for the Chezy Formula increases with the hydraulic slope and with the hydraulic radius. This is due to the fact that the exponents used for the terms in the formula are less than the true values. If the exponents were increased to correspond more nearly with the facts, the variation in the value of c would become smaller.

The Hazen-Williams Formula was designed with a view of obtaining a minimum variation in the value of c for all conduits of the same degree of roughness. That is, the object was to select values for the exponents such that c would be, as nearly as practicable, a function of the degree of roughness of the conduit surface and not of the hydraulic radius and slope.

The Hazen-Williams Formula is:

$$v = cr^{0.63}s^{0.54}0.001^{-0.04}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = Hazen-Williams coefficient of roughness.

The last term ($0.001^{-0.04}$) is a constant, and was introduced simply to equalize the value of c with the value in the Chezy Formula and other exponential formulas which may be used as a slope of 0.001 instead of at a slope of 1. Since $0.001^{-0.04}$ equals 1.318, the Hazen-Williams Formula may be written:

$$v = 1.318cr^{0.63}s^{0.54}$$

Values of Coefficient "C"

The following values of the coefficient c may be used in the Hazen-Williams Formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient c	Kind of Pipe	Coefficient c
National Duroline	148*†	Wood Stave	120
Wrought Steel	140	Riveted Steel	110
Small Brass and Copper	130	Vitrified Pipe	110
Cast Iron	130	Brick Sewers	100
Concrete	120		

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe.—Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumultaion of corrosion products, and tuberculation. However, in case of Duroline Pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Tables 15 and 16 have been prepared to furnish directly the loss of head (h_f) in feet per 1000 feet of pipe of various sizes for different velocities and values of the coefficient c. Similar data for Duroline Pipe, based on a value of $c = 148$, is given in Table 17. These tables were calculated for actual internal diameters by the following arrangement of the Hazen-Williams Formula:

$$h_f = 1000\sqrt[0.54]{\frac{v}{1.318\,cr^{0.63}}}$$

where h_f = Loss of head in feet due to friction per 1000 feet of pipe = $1000s$.

The loss of head (h_f) for any value of the coefficient c not given in Tables 15 and 16 may be determined by multiplying the loss of head (h_f) for $c = 100$ by the factor $\sqrt[0.54]{\frac{100}{c}}$

Values of this factor corresponding to various values of the coefficient c are given below:

Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$	Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$
60	2.575	110	0.8382
70	1.936	120	.7135
80	1.512	130	.6152
90	1.215	140	.5363
100	1.000		

Table 15
Loss of Head in Pipe by Friction for National A.P.I. Line Pipe, Calculated by Hazen-Williams Formula

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) c=140	c=120	c=100	c=80
1	1.049	.3	432	0.114	0.72	0.94	1.25	1.89
		4	5,760	1.485	11.4	15.2	21.4	32.3
		5	7,200	1.856	17.3	23.0	32.3	48.8
		6	8,640	2.227	24.3	32.3	45.2	68.4
		8	11,520	2.970	41.3	55.0	77.1	117.
		10	14,400	3.712	62.5	83.1	117.	176.
		12	17,280	4.455	87.6	117.	163.	247.
		16	23,040	5.940	149.	198.	278.	421.
		20	28,800	7.425	226.	300.	421.	636.
		25	36,000	9.281	341.	454.	636.	961.
		30	43,200	11.137	478.	636.	891.	1347.
		35	50,400	12.993	636.	846.	1185.	1792.
		40	57,600	14.849	814.	1083.	1518.	2295.
1¼	1.380	4	5,760	0.858	3.01	4.01	5.61	8.49
		5	7,200	1.073	4.55	6.06	8.49	12.8
		6	8,640	1.287	6.38	8.49	11.9	18.0
		8	11,520	1.716	10.9	14.5	20.3	30.6
		10	14,400	2.145	16.4	21.9	30.6	46.3
		12	17,280	2.574	23.0	30.6	42.9	64.9
		16	23,040	3.432	39.2	52.2	73.2	111.
		20	28,800	4.290	59.3	78.9	111.	167.
		30	43,200	6.435	126.	167.	234.	354.
		40	57,600	8.580	214.	285.	399.	603.
		60	86,400	12.870	454.	603.	846.	1279.
		80	115,200	17.160	773.	1028.	1441.	2178.
1½	1.610	4	5,760	0.630	1.42	1.89	2.65	4.01
		5	7,200	.788	2.15	2.86	4.00	6.06
		6	8,640	.946	3.01	4.01	5.62	8.49
		8	11,520	1.261	5.13	6.82	9.57	14.5
		10	14,400	1.576	7.76	10.3	14.5	21.9
		12	17,280	1.891	10.9	14.5	20.3	30.6
		16	23,040	2.521	18.5	24.6	34.5	52.2
		20	28,800	3.152	28.0	37.2	52.2	78.9
		30	43,200	4.728	59.3	78.9	111.	167.
		50	72,000	7.880	153.	203.	285.	431.
		75	108,000	11.820	324.	431.	603.	912.
		100	144,000	15.759	551.	734.	1028.	1554.
		125	180,000	19.699	833.	1109.	1554.	2350.
2	2.067	6	8,640	0.574	0.892	1.19	1.66	2.51
		8	11,520	765	1.52	2.02	2.83	4.28
		10	14,400	956	2.30	3.06	4.28	6.47
		12	17,280	1 147	3.22	4.28	6.00	9.07
		16	23,040	1.530	5.48	7.30	10.2	15.5
		20	28,800	1.912	8.29	11.3	15.5	23.3
		30	43,200	2.868	17.6	23.4	32.8	49.5
		50	72,000	4.781	45.2	60.2	84.3	128.
		75	108,000	7.171	95.8	128.	179.	270.
		100	144,000	9.561	163.	217.	304.	460.
		150	216,000	14.342	346.	460.	645.	975.
		200	288,000	19.122	589.	784.	1099.	1661.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) c=140	c=130	c=120	c=100
2½	2.469	8	11.520	0.536	0.639	0.733	0.851	1.19
		10	14.400	.670	.966	1.11	1.29	1.80
		12	17.280	.804	1.35	1.55	1.80	2.53
		16	23.040	1.072	2.31	2.65	3.07	4.30
		20	28.800	1.340	3.40	4.00	4.64	6.51
		25	36.000	1.675	5.27	6.05	7.02	9.83
		50	72.000	3.351	19.0	21.8	25.3	35.5
		100	144.000	6.701	68.7	78.8	91.4	128.
		150	216.000	10.052	146.	167.	194.	271.
		200	288.000	13.402	248.	284.	330.	462.
		250	360.000	16.753	375.	430.	499.	699.
		300	432.000	20.103	526.	603.	699.	980.
3	3.068	10	14.400	0.434	0.336	0.385	0.446	0.626
		15	21.600	.651	.711	.816	.946	1.33
		20	28.800	.868	1.21	1.39	1.61	2.26
		25	36.000	1.085	1.83	2.10	2.44	3.41
		50	72.000	2.170	6.61	7.58	8.79	12.3
		100	144.000	4.340	23.9	27.4	31.7	44.5
		200	288.000	8.680	86.1	98.8	115.	161.
		300	432.000	13.020	182.	209.	243.	340.
		400	576.000	17.360	311.	357.	414.	580.
		500	720.000	21.699	470.	539.	625.	876.
3½	3.548	10	14.400	0.325	0.165	0.190	0.220	0.308
		15	21.600	.487	.350	.402	.466	.653
		20	28.800	.649	.597	.684	.794	1.11
		25	36.000	.811	.902	1.03	1.20	1.68
		50	72.000	1.623	3.26	3.73	4.33	6.07
		100	144.000	3.245	11.8	13.5	15.6	21.9
		200	288.000	6.490	42.4	48.7	56.4	79.1
		300	432.000	9.735	89.9	103.	120.	168.
		400	576.000	12.980	153.	176.	204.	286.
		500	720.000	16.225	231.	266.	308.	432.
		600	864.000	19.470	324.	372.	432.	605.
4	4.026	20	28.800	0.304	0.322	0.370	0.429	0.601
		25	36.000	.630	.487	.559	.648	.909
		30	43.200	.756	.683	.784	.909	1.27
		40	57.600	1.008	1.16	1.33	1.55	2.17
		50	72.000	1.260	1.76	2.02	2.34	3.28
		100	144.000	2.520	6.35	7.28	8.45	11.8
		200	288.000	5.040	22.9	26.3	30.5	42.7
		300	432.000	7.561	48.6	55.7	64.6	90.6
		400	576.000	10.081	82.7	94.9	110.	154.
		500	720.000	12.601	125.	143.	166.	233.
		600	864.000	15.121	175.	201.	233.	327.
		800	1,152.000	20.162	299.	343.	397.	557.

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) c=140	c=130	c=120	c=100
5	5.047	30	43.200	0.481	0.227	0.261	0.302	0.424
		40	57.600	.642	.387	.441	.515	.722
		50	72.000	.802	.585	.671	.779	1.09
		100	144.000	1.604	2.11	2.42	2.81	3.94
		200	288.000	3.208	7.63	8.75	10.1	14.2
		300	432.000	4.812	16.2	18.5	21.5	30.1
		400	576.000	6.416	27.5	31.6	36.6	51.3
		500	720.000	8.020	41.6	47 7	55.3	77.6
		750	1,080.000	12.030	88.2	101.	117.	164.
		1000	1,440.000	16.040	150.	172.	200.	280.

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) c=140	c=130	c=120	c=100
6	6.065	50,000	0.0774	0.386	0.122	0.140	0.162	0.227
		60,000	0.928	.463	.171	.196	.227	.318
		80,000	.124	.617	.291	.333	.387	.542
		100,000	.155	.771	.439	.504	.585	.819
		200,000	.309	1.542	1.59	1.82	2.11	2.96
		300,000	.464	2.314	3.36	3 85	4.47	6.27
		400,000	.619	3.085	5.72	6.57	7.62	10.7
		600,000	.928	4.627	12.1	13.9	16.1	22.6
		800,000	1.238	6.170	20.7	23.7	27.5	38.5
		1,000,000	1.547	7.712	31.2	35.8	41.6	58.2
		1,500,000	2.321	11.568	66.2	75.9	88.1	123.
		2,000,000	3.094	15.424	113.	129.	150.	210.
8	7.981	200,000	0.309	0.891	0.416	0.478	0.554	0.777
		300,000	.464	1.336	.882	1.01	1.17	1.65
		400,000	.619	1.781	1.50	1.72	2.00	2.80
		500,000	.774	2.227	2.27	2.61	3.02	4.24
		750,000	1.160	3.340	4.82	5.52	6.41	8.98
		1,000,000	1.547	4.454	8.20	9.41	10.9	15.3
		1,500,000	2.321	6.680	17.4	19.9	23.1	32.4
		2,000,000	3.094	8.907	29.6	34.0	39.4	55.2
		3,000,000	4.642	13.361	62.7	72.0	83.5	117.
10	10.020	300,000	0.464	0.848	0.291	0.334	0.388	0.543
		400,000	.619	1.130	.496	.569	.660	.926
		500,000	.774	1.413	.750	.861	.998	1.40
		750,000	1.160	2.119	1.59	1.82	2.12	2.96
		1,000,000	1.547	2.825	2.71	3.11	3.60	5.05
		2,000,000	3.094	5.651	9.78	11.2	13.0	18.2

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) c=140	c=130	c=120	c=100
10	10.020	3,000,000	4.642	8.476	20.7	23.8	27.6	38.6
		4,000,000	6.189	11.302	35.3	40.5	47.0	65.8
		5,000,000	7.736	14.127	53.4	61.2	71.0	99.5
12	12.000	300,000	0.464	0.591	0.121	0.139	0.161	0.226
		400,000	.619	.788	.206	.237	.274	.385
		500,000	.774	.985	.312	.358	.415	.581
		1,000,000	1.547	1.970	1.13	1.29	1.50	2.10
		1,500,000	2.321	2.955	2.38	2.74	3.17	4.45
		2,000,000	3.094	3.940	4.06	4.66	5.40	7.58
		3,000,000	4.642	5.910	8.61	9.87	11.5	16.1
		5,000,000	7.736	9.850	22.2	25.4	29.5	41.3
		7,500,000	11.60	14.775	47.0	53.9	62.5	87.6
		10,000,000	15.47	19.700	80.0	91.8	106.	149.
14 O D	13.250	500,000	0.774	0.808	0.192	0.221	0.256	0.359
		1,000,000	1.547	1.616	.695	.797	.924	1.30
		2,000,000	3.094	3.232	2.51	2.88	3.34	4.68
		3,000,000	4.642	4.847	5.31	6.09	7.07	9.91
		5,000,000	7.736	8.079	13.7	15.7	18.2	25.5
		7,500,000	11.60	12.119	29.0	33.3	38.6	54.1
		10,000,000	15.47	16.158	49.4	56.6	65.7	92.1
		12,500,000	19.34	20.198	74.7	85.6	99.3	139.
16 O D	15.250	750,000	1.160	0.915	0.206	0.236	0.274	0.383
		1,000,000	1.547	1.220	.350	.402	.466	.653
		2,000,000	3.094	2.440	1.26	1.45	1.68	2.36
		3,000,000	4.642	3.659	2.68	3.07	3.56	5.00
		5,000,000	7.736	6.099	6.90	7.91	9.18	12.9
		7,500,000	11.60	9.148	14.6	16.8	19.4	27.3
		10,000,000	15.47	12.198	24.9	28.6	33.1	46.4
		15,000,000	23.21	18.297	52.8	60.5	70.2	98.4
18 O D	17.182	1,000,000	1.547	.961	0.196	0.225	0.261	0.365
		2,000,000	3.094	1.922	.707	.811	.941	1.32
		3,000,000	4.642	2.883	1.50	1.72	1.99	2.79
		5,000,000	7.736	4.805	3.86	4.43	5.13	7.20
		7,500,000	11.60	7.207	8.18	9.38	10.9	15.2
		10,000,000	15.47	9.609	13.9	16.0	18.5	26.0
		15,000,000	23.21	14.414	29.5	33.9	39.3	55.0
		20,000,000	30.94	19.218	50.3	57.7	66.9	93.8
20 O D	19.182	1,000,000	1.547	0.771	0.115	0.131	0.152	0.214
		2,000,000	3.094	1.542	.414	.475	.550	.771
		3,000,000	4.642	2.313	.876	1.01	1.17	1.63
		5,000,000	7.736	3.855	2.26	2.59	3.00	4.21
		7,500,000	11.60	5.782	4.78	5.49	6.36	8.92
		10,000,000	15.47	7.710	8.15	9.35	10.8	15.2
		15,000,000	23.21	11.565	17.3	19.8	23.0	32.2
		20,000,000	30.94	15.419	29.4	33.7	39.1	54.8

Table 16

Loss of Head in Pipe by Friction for Large Diameter Pipe Listed by I. D. Sizes, Calculated by Hazen-Williams Formula

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
22	1.8333	1	1.547	0.586	0.059	0.067	0.078	0.110
		2.5	3.868	1.465	.321	.368	.427	.598
		5	7.736	2.931	1.16	1.33	1.54	2.16
		7.5	11.60	4.396	2.45	2.81	3.26	4.57
		10	15.47	5.861	4.18	4.79	5.56	7.79
		15	23.21	8.792	8.86	10.2	11.8	16.5
		20	30.94	11.722	15.1	17.3	20.1	28.1
		25	38.68	14.653	22.8	26.2	30.3	42.5
24	2.0000	2	3.094	0.985	0.139	0.159	0.185	0.259
		5	7.736	2.462	.758	.869	1.01	1.41
		7.5	11.60	3.694	1.61	1.84	2.14	2.99
		10	15.47	4.925	2.74	3.14	3.64	5.10
		15	23.21	7.387	5.80	6.65	7.71	10.8
		20	30.94	9.850	9.87	11.3	13.1	18.4
		25	38.68	12.312	14.9	17.1	19.9	27.8
		30	46.42	14.775	20.9	24.0	27.8	39.0
26	2.1667	2	3.094	0.839	0.094	0.108	0.125	0.175
		5	7.736	2.098	.513	.589	.683	.957
		7.5	11.60	3.147	1.09	1.25	1.45	2.03
		10	15.47	4.196	1.85	2.12	2.46	3.45
		15	23.21	6.295	3.93	4.50	5.22	7.32
		20	30.94	8.393	6.69	7.67	8.90	12.5
		25	38.68	10.491	10.1	11.6	13.4	18.8
		30	46.42	12.589	14.2	16.3	18.8	26.4
28	2.3333	2	3.094	0.724	0.066	0.075	0.087	0.122
		5	7.736	1.809	.358	.410	.476	.667
		7.5	11.60	2.714	.758	.869	1.01	1.41
		10	15.47	3.618	1.29	1.48	1.72	2.41
		15	23.21	5.428	2.74	3.14	3.64	5.10
		20	30.94	7.237	4.66	5.35	6.20	8.69
		25	38.68	9.046	7.05	8.08	9.37	13.1
		30	46.42	10.855	9.88	11.3	13.1	18.4
30	2.5000	5	7.736	1.576	0.256	0.293	0.340	0.477
		10	15.47	3.152	.923	1.06	1.23	1.72
		15	23.21	4.728	1.96	2.24	2.60	3.65
		20	30.94	6.304	3.33	3.82	4.43	6.21
		25	38.68	7.880	5.03	5.78	6.70	9.39
		30	46.42	9.456	7.06	8.10	9.39	13.2
		35	54.15	11.032	9.39	10.8	12.5	17.5
		40	61.89	12.608	12.0	13.8	16.0	22.4
36	3.0000	5	7.736	1.094	0.105	0.121	0.140	0.196
		10	15.47	2.189	.380	.436	.505	.708
		15	23.21	3.283	.804	.923	1.07	1.50
		20	30.94	4.378	1.37	1.57	1.82	2.56
		30	46.42	6.567	2.90	3.33	3.86	5.41
		40	61.89	8.756	4.95	5.67	6.58	9.22
		50	77.36	10.944	7.48	8.58	9.95	13.9
		60	92.83	13.133	10.5	12.0	13.9	19.5

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
42	3.50	5	7.736	0.804	0.050	0.057	0.066	0.093
		10	15.47	1.608	.179	.206	.238	.334
		15	23.21	2.412	.380	.436	.505	.708
		20	30.94	3.216	.647	.742	.861	1.21
		30	46.42	4.824	1.37	1.57	1.82	2.56
		40	61.89	6.433	2.34	2.68	3.11	4.35
		50	77.36	8.041	3.53	4.05	4.70	6.58
		75	116.0	12.061	7.48	8.58	9.95	13.9
48	4.00	5	7.736	0.616	0.026	0.030	0.034	0.048
		10	15.47	1.231	.094	.107	.124	.174
		20	30.94	2.462	.338	.387	.449	.630
		30	46.42	3.694	.715	.821	.952	1.33
		40	61.89	4.925	1.22	1.40	1.62	2.27
		50	77.36	6.156	1.84	2.11	2.45	3.44
		75	116.0	9.234	3.90	4.48	5.19	7.28
		100	154.7	12.312	6.65	7.63	8.85	12.4
54	4.50	10	15.47	0.973	0.053	0.060	0.070	0.098
		20	30.94	1.946	.190	.218	.253	.355
		30	46.42	2.919	.403	.462	.536	.752
		40	61.89	3.891	.687	.788	.913	1.28
		50	77.36	4.864	1.04	1.19	1.38	1.94
		75	116.0	7.296	2.20	2.52	2.93	4.10
		100	154.7	9.728	3.75	4.30	4.98	6.99
		125	193.4	12.160	5.66	6.50	7.54	10.6
60	5.00	10	15.47	0.788	0.032	0.036	0.042	0.059
		20	30.94	1.576	.114	.131	.151	.212
		30	46.42	2.364	.241	.277	.321	.450
		40	61.89	3.152	.411	.471	.547	.766
		50	77.36	3.940	.621	.713	.827	1.16
		75	116.0	5.910	1.32	1.51	1.75	2.45
		100	154.7	7.880	2.24	2.57	2.98	4.18
		125	193.4	9.850	3.39	3.89	4.51	6.32
66	5.50	10	15.47	0.651	0.020	0.023	0.026	0.037
		20	30.94	1.302	.072	.082	.095	.133
		30	46.42	1.954	.152	.174	.202	.283
		50	77.36	3.256	.391	.448	.520	.728
		75	116.0	4.884	.828	.949	1.10	1.54
		100	154.7	6.512	1.41	1.62	1.88	2.63
		125	193.4	8.140	2.13	2.44	2.84	3.97
		150	232.1	9.769	2.99	3.43	3.97	5.57
72	6.00	10	15.47	0.547	0.013	0.015	0.017	0.024
		25	38.68	1.368	.071	.081	.094	.132
		50	77.36	2.736	.256	.293	.340	.477
		75	116.0	4.104	.542	.621	.721	1.01
		100	154.7	5.472	.923	1.06	1.23	1.72
		125	193.4	6.840	1.40	1.60	1.86	2.60
		150	232.1	8.208	1.96	2.24	2.60	3.65
		175	270.8	9.576	2.60	2.98	3.46	4.85

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Cubic feet per second	Million gallons per 24 hours		c=140	c=130	c=120	c=100
78	6.50	25	16.16	0.753	0.021	0.025	0.028	0.040
		50	32.32	1.507	.077	.089	.103	.144
		75	48.47	2.260	.163	.188	.217	.305
		100	64.63	3.014	.278	.319	.371	.519
		150	96.95	4.520	.590	.677	.785	1.10
		200	129.3	6.027	1.01	1.15	1.34	1.87
		250	161.6	7.534	1.52	1.74	2.02	2.83
		300	193.9	9.041	2.13	2.44	2.83	3.97
84	7.00	25	16.16	0.650	0.015	0.017	0.020	0.028
		50	32.32	1.299	.054	.062	.072	.100
		75	48.47	1.949	.114	.131	.152	.212
		100	64.63	2.598	.194	.223	.258	.362
		150	96.95	3.898	.411	.472	.547	.767
		200	129.3	5.197	.701	.804	.932	1.31
		250	161.6	6.496	1.06	1.22	1.41	1.98
		300	193.9	7.795	1.48	1.70	1.98	2.77
90	7.50	25	16.16	0.566	0.011	0.012	0.014	0.020
		50	32.32	1.132	.038	.044	.051	.072
		75	48.47	1.698	.081	.093	.108	.152
		100	64.63	2.264	.139	.159	.185	.259
		150	96.95	3.395	.294	.337	.391	.548
		200	129.3	4.527	.501	.574	.666	.934
		300	193.9	6.791	1.06	1.22	1.41	1.98
		400	258.5	9.054	1.81	2.07	2.40	3.37
96	8.00	25	16.16	0.497	0.008	0.009	0.010	0.014
		50	32.32	0.995	.028	.032	.037	.052
		100	64.63	1.989	.101	.116	.135	.189
		150	96.95	2.984	.215	.246	.286	.400
		200	129.3	3.979	.366	.419	.486	.682
		300	193.9	5.968	.775	.889	1.03	1.44
		400	258.5	7.958	1.32	1.51	1.76	2.46
		500	323.2	9.947	2.00	2.29	2.65	3.72

The Scobey Formula

Fred C. Scobey,* Senior Irrigation Engineer of the Division of Agricultural Engineering, U. S. Department of Agriculture, offers the following formulas which he says "include viscosity influence for a temperature of 15° C. (59° F.) and differentiate between various types and classes of sheet and plate metal pipe by means of coefficients, which are themselves constant throughout the whole range of sizes and velocities for a given class of pipe":

$$hf = \frac{K_s v^{1.9}}{D^{1.1}}$$

$$v = \frac{hf^{.0526} D^{.58}}{K_s{}^{.0526}}$$

where hf = Loss of head in feet due to friction per 1000 feet of pipe.
D = Mean inside diameter of pipe in feet.
v = Mean velocity of the water in feet per second.
K_s = General coefficient. (K'_s is this value for new pipe.)

Scobey limited his study to pipe of nominal size, four inch and larger, and assumed that the interior of all pipe would be chemically protected with a coating which would form the true interior surface, at least during the first years of the life of the conduit.

He divides sheet and plate metal pipe into three major classes:

Class 1—"Full-riveted" pipe, having both longitudinal and girth seams held by one or more lines of rivets with projecting

*United States Department of Agriculture Technical Bulletin No. 150 "The Flow of Water in Riveted Steel and Analogous Pipes" (1930).

Table 17

Loss of Head in Pipe by Friction for National Duroline Pipe*
Calculated by the Hazen-Williams Formula

Pipe size, inches	Average inside diameter, inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (hr) ($c = 148$)
½	0.484	1	1,440	1.74	35.0
		2	2,880	3.48	126.0
		3	4,320	5.23	265.0
		4	5,760	6.97	455.0
		5	7,200	8.72	685.0
		6	8,640	10.46	970.0
		8	11,520	13.95	1650.0
		10	14,400	17.44	2500.0
¾	0.686	2	2,880	1.73	22.8
		3	4,320	2.60	48.0
		4	5,760	3.47	82.0
		5	7,200	4.34	124.0
		6	8,640	5.21	173.0
		8	11,520	6.94	295.0
		10	14,400	8.68	443.0
		15	21,600	13.02	946.0
		20	28,800	17.36	1590.0
1	0.896	3	4,320	1.52	13.2
		4	5,760	2.03	22.2
		5	7,200	2.54	34.5
		6	8,640	3.05	47.5
		8	11,520	4.07	81.0
		10	14,400	5.08	120.0
		12	17,280	6.10	170.0
		14	20,160	7.12	225.0
		16	23,040	8.14	290.0
		20	28,800	10.16	432.0
		25	36,000	12.70	630.0
		30	43,200	15.24	925.0
1¼	1.175	4	5,760	1.18	5.8
		5	7,200	1.47	9.0
		6	8,640	1.77	12.6
		7	10,080	2.07	16.7
		8	11,520	2.36	21.5
		10	14,400	2.95	32.5
		12	17,280	3.55	45.5
		14	20,160	4.14	59.0
		16	23,040	4.73	77.0
		18	25,920	5.32	96.0
1¼	1.175	20	28,800	5.91	116.0
		25	36,000	7.39	175.0
		30	43,200	8.87	245.0
		40	57,600	11.80	420.0
		60	86,400	17.70	880.0
1½	1.405	4	5,760	0.82	2.60
		5	7,200	1.03	3.95
		6	8,640	1.24	5.28
		7	10,080	1.44	7.3
		8	11,520	1.65	9.4
		9	12,960	1.86	11.6
		10	14,400	2.06	14.2
		12	17,280	2.48	19.8
		14	20,160	2.89	26.4
		16	23,040	3.31	34.5
		18	25,920	3.72	42.0
		20	28,800	4.13	51.0
		22	31,680	4.55	61.0
		24	34,560	4.96	72.0
		26	37,440	5.38	83.0
		28	40,320	5.79	95.0
		30	43,200	6.20	108.0
		35	50,400	7.24	135.0
		40	57,600	8.27	176.0
		50	72,000	10.34	266.0
		75	108,000	15.51	562.0
		100	144,000	20.69	960.0
2	1.780	6	8,640	0.77	1.66
		8	11,520	1.03	2.82
		10	14,400	1.28	4.30
		12	17,280	1.54	6.0
		14	20,160	1.80	8.0
		16	23,040	2.06	10.2
2	1.780	18	25,920	2.32	12.7
		20	28,800	2.57	15.5
		25	36,000	3.22	23.2
		30	43,200	3.86	33.0
		35	50,400	4.51	44.0
		40	57,600	5.15	56.0
		45	64,800	5.80	77.0
		50	72,000	6.44	84.0
		55	79,200	7.09	100.0
		60	86,400	7.73	117.0
		65	93,600	8.37	135.0
		70	100,800	9.02	157.0
		75	108,000	9.66	177.0
		100	144,000	12.89	302.0
		150	216,000	19.33	570.0
2½	2.182	8	11,250	0.68	1.05
		10	14,400	.85	1.58
		12	17,280	1.02	2.25
		16	23,040	1.37	3.85
		25	36,000	2.14	8.6
		50	72,000	4.29	31.5
		100	144,000	8.58	113.0
		150	216,000	12.87	240.0
		200	288,000	17.16	410.0
		250	360,000	21.45	620.0
3	2.725	10	14,400	0.55	0.54
		15	21,600	.82	1.15
		20	28,800	1.10	1.95
		25	36,000	1.37	2.95
		50	72,000	2.75	10.6
		80	115,200	4.40	25.3
		100	144,000	5.50	38.5
		160	230,400	8.80	90.0
		200	288,000	11.00	136.0
		300	432,000	16.50	290.0
		400	576,000	22.00	500.0
		500	720,000	27.50	750.0
3½	3.205	10	14,400	0.39	0.24
		15	21,600	.59	.52
		20	28,800	.79	.88
		25	36,000	.99	1.34
		50	72,000	1.98	4.8
		80	115,200	3.18	11.5
		100	144,000	3.97	17.5
		160	230,400	6.36	41.5
		200	288,000	7.95	63.0
		300	432,000	11.93	135.0
		400	576,000	15.90	225.0
		500	720,000	19.88	340.0
4	3.620	20	28,800	0.62	0.49
		25	36,000	.77	.74
		30	43,200	.93	1.04
		50	72,000	1.55	2.68
		80	115,200	2.49	6.4
		100	144,000	3.11	9.7
		160	230,400	4.98	23.4
		200	288,000	6.23	35.0
		300	432,000	9.35	72.2
		400	576,000	12.46	124.0
		500	720,000	15.58	187.0
5	4.548	30	43,200	0.59	0.34
		40	57,600	.79	.58
		50	72,000	.98	.87
		80	115,200	1.58	2.10
		100	144,000	1.97	3.15
		160	230,400	3.16	7.7
		200	288,000	3.95	11.5
		300	432,000	5.92	24.2
		400	576,000	7.90	41.2
		500	720,000	9.87	61.8
		750	1,080,000	14.81	131.0
6	5.440	50,000	.0774	0.47	0.20
		60,000	.0928	.57	.26
		80,000	.1238	.76	.44
		100,000	.1547	.95	.66
		140,000	.2166	1.34	1.25
		200,000	.3094	1.91	3.42
		300,000	.4642	2.87	5.2
		400,000	.619	3.83	8.7
		500,000	.774	4.79	13.2
		600,000	.928	5.75	18.5
		800,000	1.238	7.67	31.5
		1,000,000	1.547	9.58	48.0
		1,500,000	2.321	14.37	100.0
		2,000,000	3.094	19.17	170.0
8	7.446	200,000	.3094	1.02	0.53
		300,000	.4642	1.53	1.12
		360,000	.557	1.84	1.57
		400,000	.619	2.04	1.92
		500,000	.774	2.55	2.88
		600,000	.928	3.06	4.05
		700,000	1.083	3.58	5.4
		800,000	1.238	4.09	6.9
		900,000	1.392	4.60	8.6
		1,000,000	1.547	5.11	10.5
		1,200,000	1.857	6.13	14.6
8	7.356	200,000	.3094	1.04	0.56
		300,000	.4642	1.57	1.18
		400,000	.619	2.09	2.00
		500,000	.774	2.62	3.05
		600,000	.928	3.14	4.30
		700,000	1.083	3.66	5.7
		800,000	1.238	4.19	7.3
		1,000,000	1.547	5.24	11.2
		1,500,000	2.321	7.86	23.8
		2,000,000	3.094	10.48	40.0
		3,000,000	4.642	15.72	84.0
10	9.443	300,000	.4642	0.95	0.35
		400,000	.619	1.27	.60
		500,000	.774	1.59	.90
		600,000	.928	1.90	1.26
		750,000	1.160	2.38	1.92
		1,000,000	1.547	3.18	3.25
		1,500,000	2.321	4.77	6.9
		2,000,000	3.094	6.36	11.8
		3,000,000	4.642	9.54	25.0
		4,000,000	6.188	12.72	42.5

*Pipe lined with a highly resistant cement-base composition lining.—Ed.

heads. From the capacity standpoint, pipe with countersunk rivet heads on the interior belong in *Class* 3.

Class 2—"Girth-riveted" pipe, having no retarding rivet heads in the longitudinal seams, but having the same girth seams as full-riveted pipe.

Class 3—"Continuous-interior" pipe, having the interior surface unmarred by plate offsets or by projecting rivet heads in either longitudinal or girth seams. Not necessarily described as "smooth."

For these classes Scobey suggests the following coefficients for new pipe:

Class 1*a*, $K'_s = 0.38$ for new sheet metal pipe up to three-sixteenths of an inch thick.

Class 1*b*, $K'_s = 0.44$ for new plate metal pipe on three-sixteenths to seven-sixteenths of an inch thick, with either taper or cylinder joints.

Class 1*c*, $K'_s = 0.48$ for new plate metal pipe from one-half inch up, with either taper or cylinder joints, and for plate from one-fourth to seven-sixteenths of an inch thick when butt-jointed.

Class 1*d*, $K'_s = 0.52$ for new butt-strap pipe of plate from one-half inch up.

Class 2*d*, $K'_s = 0.34$ for new girth-riveted pipe. This includes all sheet and plate metal pipe with continuous seamed lognitudinal joints but with girth joints, particularly field joints, made with the usual rivet heads inside the pipe.

Class 3, $K'_s = 0.32$ for new continuous-interior pipe. This class comprises all type of sheet and plate metal pipe that offer a practically uniform interior surface of relative smoothness. "Continuous-interior" is offered as descriptive of an interior surface unbroken by rivet heads or appreciable shell-thickness offsets. Use of the apparently obvious synonym "smooth" has purposely been avoided, as this description might hold only while the pipe is new.

NOTE: Although Scobey confines his paper to the discussion of sheet and plate metal pipe, *Classes* 2 and 3 also apply to seamless pipe as well as to lap-weld, hammer-weld, and electric-weld pipe.

It should be noted that the coefficients (K'_s) given above

are for new pipe. Concerning the deterioration of carrying capacity with age, Scobey states:

"It has long been appreciated that all metal pipe deteriorates in carrying capacity; the rate of decrease being dependent on the efficiency of the pipe coating, the composition and treatment of the pipe material, and the activity of the water conveyed in the pipe. Filtered and treated water causes less deterioration than raw water. Long lines deteriorate more rapidly at the upper ends than at the lower ends. "So far as available data indicate, the increase in the value of K_s with age, is expressed by the formula:

$$K_s = K'_s e^{0.035t}$$

where e = Base of Naperian logarithms (2.7183).
t = Age of pipe in years.
When t is zero, then K_s becomes K'_s."

[NOTE: Tables showing various values of K_s and corresponding losses of head at various velocities and also values of $v^{1.9}$ have had to be omitted. For a copy of these address National Tube Co., Pittsburgh, Pa., asking for Technical Bulletin No. 21. —Ed.]

Fig. 36, which was taken from United States Department of Agriculture Technical Bulletin No. 150, will be found useful in making estimates and preliminary studies. It gives the relation between discharge, pipe diameter, velocity, and loss of head for various values of the coefficient K_s. Values of K_s for ages of 0 to 50 years corresponding to various values of K'_s are also given.

The lower age diagram on the chart is based on the formula $K_s = K'_s e^{0.035t}$ and is to be used for aggressive waters. The upper age diagram is based on the formula $K_s = K'_s e^{0.01t}$ and is intended for use where the waters are known to be non-aggressive.

The following example will illustrate the method of using this chart:

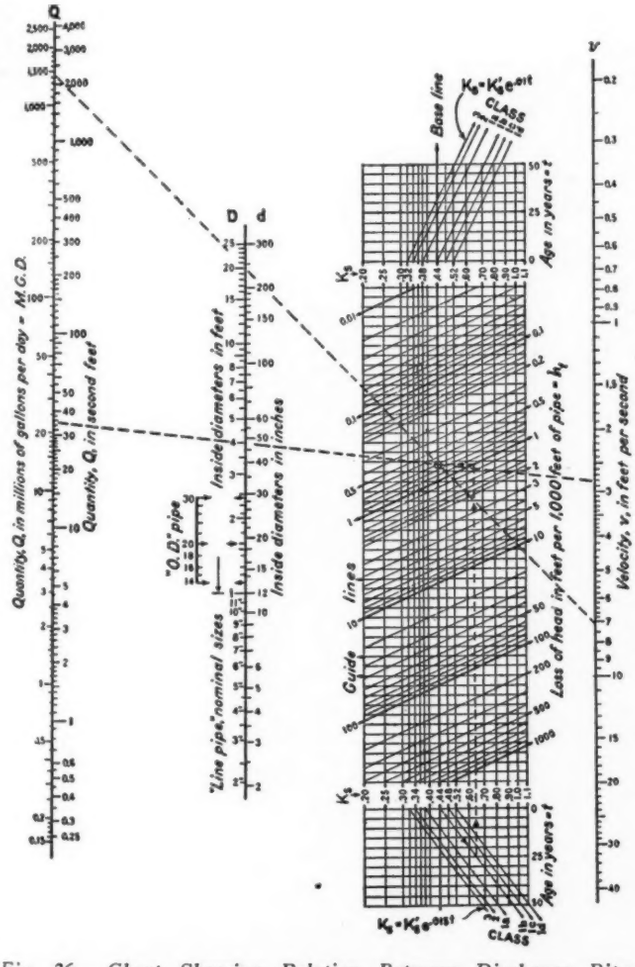

Q
Quantity, Q, in millions of gallons per day = M.G.D.
Quantity, Q, in second feet
D d
Inside diameters in feet
Inside diameters in inches
"O.D." pipe
"Line pipe," nominal sizes
Guide lines
Base line
Age in years = t
Loss of head in feet per 1,000 feet of pipe = h_f
Velocity, v, in feet per second
v

Fig. 36 — Chart Showing Relation Between Discharge Pipe Diameter, Velocity, and Loss of Head for Various Values of the Coefficient K_s and K_{s1} in Scobey Formula

Table 21

Special Losses of Head in Terms of $v^2/2g$ (From Hydraulics, by Ernest W. Schoder and Francis M. Dawson—Second Edition, 1934, with Modifications)

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Entrance	
Square-edged entry. Upstream end of pipe perpendicular to, and flush with inside face of reservoir wall	0.50
Projecting pipe at entry or re-entrant pipe end	1.00
Well-rounded entry	0.02 to 0.05
Curves and Fittings	
Easy curves or bends of very large radius, and smooth inside, of same inside diameter throughout as the pipe line. Excess loss over same length of straight pipe	0.05 to 0.15
90-degree curves, fairly smooth, same inside diameter as pipe; Radius of center line = diameter of pipe	0.50
Radius of center line = 2 to 8 times diameter of pipe	0.25
90-degree common screw end pipe elbows, short turn, inside larger than pipe	0.75
Tees, common screw end, full-size branch, flow deviated 90 degrees	1.50
Square elbow (intersection of two cylinders, corner not rounded at outside or inside of curve.)	1.25
Obtuse-angled elbows, (deflection of pipe less than 90 degrees); multiply values for square elbow or 90-degree curve by $\left(\frac{\text{deflection, degrees}}{90 \text{ degrees}}\right)^2$	
Water Meters (Subject to much variation)	
Disk or "wobble-disk" type	3.4 to 10
Rotary type (star or cog-wheel-shaped disk as piston)	10
Reciprocating piston type (like a piston pump)	15
Turbine-wheel type (double flow, balanced)	5 to 7.5
Diaphragm and Orifice Meters	
Diaphragm of thin material across pipe, with concentric hole, or an inside projecting washer or gasket, or a "burr", due to cutting pipe with a wheel cutter: Diameter of hole = 0.91 × diameter of pipe	0.34
Diameter of hole = 0.80 × diameter of pipe	1.88
(Note that $v^2/2g$ in this particular case refers to pipe, not to the area of opening, nor to the contracted stream through opening.)	
Nozzles	
Nozzles: when the coefficient of velocity and discharge ranges from 0.99 to 0.975, the loss of head ranges from	0.02 to 0.05 (Where v is the velocity of the issuing jet)

*Note: Except where otherwise noted, v is the mean velocity in the pipe.

Assume that it is desired to know what conditions will prevail in a pipe line constructed of full-riveted pipe (*Class* 1*b*) after carrying aggressive waters for a period of 25 years.

From page 45 the coefficient K_s for new pipe of *Class* 1*b* is found to be 0.44. On the lower age diagram follow the diagonal line representing $K_s = 0.44$ (at 0 age) until it intersects the horizontal line representing an age of 25 years. From this point of intersection proceed vertically on the dashed line (which represents $K_s = 0.64$) until it intersects the slope line of 1 foot per 1000 feet of pipe. From this point follow the guide lines to the vertical base line. Using this point (marked on the chart by a circle) as a pivot, a straight edge will give simultaneous values of discharge (Q) diameter (D or d) and velocity (v). This is illustrated by dashed lines for 20 feet and 4 feet inside diameter pipe. The dashed line through the pivot point and the point representing pipe of 20 feet inside diameter shows that a discharge of 2250 cubic feet per second and a velocity of 7.2 feet per second can be expected. The other dashed line through the pivot point and through the point representing pipe 4 feet inside diameter indicates a discharge of 36 cubic feet per second and a velocity of 2.8 feet per second.

Special Losses of Head

Curves, elbows, tees, meters, enlargements, contractions, etc., in a pipe line cause losses of head, which, if of consequence, must be allowed for in addition to the loss of head ordinarily encountered in straight pipe of uniform cross section.

Special losses may be expressed as equivalent lengths of straight pipe which would cause the same loss of head, or as decimals or multiples of $v^2/2g$, where v is the mean velocity in the pipe. For any particular special fittings, experiments show that the loss of head is not in all cases a constant fraction of

Table 21—Concluded

Special Losses of Head in Terms of $v^2/2g$

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Venturi Meter Tubes	
Venturi meter tubes: the loss of head occurs mostly in and downstreamwards from the divergence, the loss between upstream end and throat being only 0.03 to $0.06 \times v^2/2g$, where v is the throat velocity. The total loss through the meter is:	
For total angle of divergence = ±5 degrees	$\frac{1}{7}$ to $\frac{1}{10}$ Where v is the throat velocity
For total angle of divergence = ±15 degrees	$\frac{1}{3}$ to $\frac{1}{6}$
(The lower values go with large throats, and the larger values with small throats whose diameter is from ⅕ to ½ the diameter of the pipe.)	
Sudden Enlargement	
Sudden enlargement, from a small pipe ending abruptly where a larger pipe begins, is found to involve loss of head fairly close in accordance with Borda's Formula which is: Loss of head $= \frac{(v_1 - v_2)^2}{2g}$ (Note that this is not the difference of the velocity heads, but is the head corresponding to the difference of the velocities.) The above-stated formula may be written: Loss of head $= \left(1 - \frac{A_1}{A_2}\right)^2 \frac{v_1^2}{2g}$, or for a circular or square pipe: Loss of head $= \left[1 - \left(\frac{d_1}{d_2}\right)^2\right]^2 \times \frac{v_1^2}{2g}$ where A_1, v_1 and d_1 refer to the smaller upstream pipe, while the subscript 2 refers to the larger downstream pipe.	
Sudden Square-Edged Reductions	
Sudden square-edged reductions in pipes. When the sudden reduction of pipe is very large, say $d_2/d_1 = 0.1$, the loss of head is practically as given for square-edged entry, i.e., loss of head $= 0.40 v_2^2/2g$. For smaller reductions the value of K is smaller, but the experimental data of Weisbach (1855) and Brightmore (1907) do not agree. For ratios $d_2/d_1 =$ 0.5, 0.75, and 0.9 the value K is about 0.33, 0.20 and 0.08, respectively. In this case the subscript 2 refers to the smaller downstream pipe, and K is the factor which, multiplied by $v_2^2/2g$, gives the loss of head.	

*Note: Except where otherwise noted, the v is mean velocity in the pipe.

$v^2/2g$, but that the fraction varies somewhat with the velocity. For most practical purposes, however, the values given in 21 may be relied on as safe average values.

Water Hammer

When a valve in a water line is closed while the water is flowing, the velocity of the water upstream from the valve is reduced and a dynamic pressure is exerted in addition to the normal static pressure. This dynamic pressure, commonly called "water hammer," is the result of the transformation of the kinetic energy of the moving mass of water into pressure energy which expends itself (unless relief devices are provided) by compressing the water and stretching the pipe walls. When a valve is closed suddenly, the magnitude of the dynamic pressure produced is frequently much greater than the static pressure on the line, and may cause fracture of the pipe or fittings.

Starting at the suddenly-closed valve, a wave of increased pressure is transmitted back through the pipe with constant velocity and intensity. When the pressure wave has traveled upstream to the end of the pipe, where there is a reservoir or large main, the elasticity of the compounded water and of the expanded pipe reverse the flow and a wave of normal pressure travels downstream, the flow being progressively reversed as the water expands.

If the water were incompressible and the pipe inelastic, the instantaneous closure of the valve would create an infinite pressure. Since it is impossible to close a valve instantaneously, it is apparent that a series of pressure waves is created, causing an increased pressure at the valve. If the valve is completely closed before the first pressure wave has time to return to the valves as a wave of low pressure, the pressure increases continually up to the time of complete closure and the resulting pressure is just the same as if the valve had been instantaneously closed. The velocity of the pressure wave depends upon the ratio of wall-thickness to inside pipe diameter and on the modulus of elasticity of the water and of the pipe material according to the formula:

$$S = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

The head due to water hammer in excess of normal static head is proportional to the destroyed velocity and to the velocity of the pressure wave along the pipe. Since the intensity of the excess head depends upon the destroyed velocity, the same excess pressure is produced by suddenly reducing the velocity from 6 to 3 feet per second, as by entirely stopping a velocity of 3 feet per second. The excess head due to water hammer is given by the formula:

$$h = \frac{12\,v}{g\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

where S = Velocity of pressure wave along pipe in feet per second.
w = Weight of water in pounds per cubic foot.
h = Head due to water hammer (in excess of static head).
g = Acceleration of gravity.
t = Wall-thickness of pipe in inches.
d = Inside diameter of pipe in inches.
E_p = Modulus of elasticity of pipe material in pounds per square inch.
E_w = Modulus of elasticity of water in pounds per square inch.
v = Destroyed velocity in feet per second.

By inserting values for g, w, E_w and E_p the two formulas may be simplified. Thus, if
$g = 32.174$ feet per second per second.
$w = 62.4096$ pounds per cubic foot (at 50° F.)
$E_w = 300{,}000$ pounds per square inch.
$E_p = 29{,}000{,}000$ pounds per square inch (for steel pipe)
the formulas reduce to:

$$S = \frac{4720}{\sqrt{1 + .0103\frac{d}{t}}}$$

$$h = \frac{147\,v}{\sqrt{1 + .0103\frac{d}{t}}}$$

If the flow is not checked rapidly, so that the wave from the first movement of the valve has time to travel upstream to the end and back again several times while the valve closing is in progress, the excess pressure is greatly reduced. Therefore, it is advisable to use slow closing valves or to provide air chambers or surge tanks in the line to absorb the shock due to water hammer.

Measurement of Flowing Water

Pitot Tubes

Pitot tubes are used to measure the velocity of flowing water. Such a tube consists essentially of a vertical tube, the lower end of which is bent at 90° so that its open end is directed against the current. The velocity of the flowing water causes the water to rise in the vertical leg of the pitot tube a distance above the free surface of the stream equal to the velocity head.

When a pitot tube is inserted into a pipe carrying water under pressure, the water will rise in the vertical leg of the tube a distance equal to the sum of the pressure head and the velocity head at the point where the tube is inserted. If a piezometer tube is tapped into the wall of the pipe at substantially the same point, the water will rise in this tube a distance equal to the pressure head at that point. The difference in the levels of the water in the two tubes will therefore be equal to the velocity head in the pipe at the point where the tubes are inserted. Fig. 37 shows such an arrangement. The height of the water in the pitot tube is equal to the sum of the pressure head, h_p, and the velocity head, h_v. The height of the water in the piezometer tube is equal to the pressure head, h_p. The

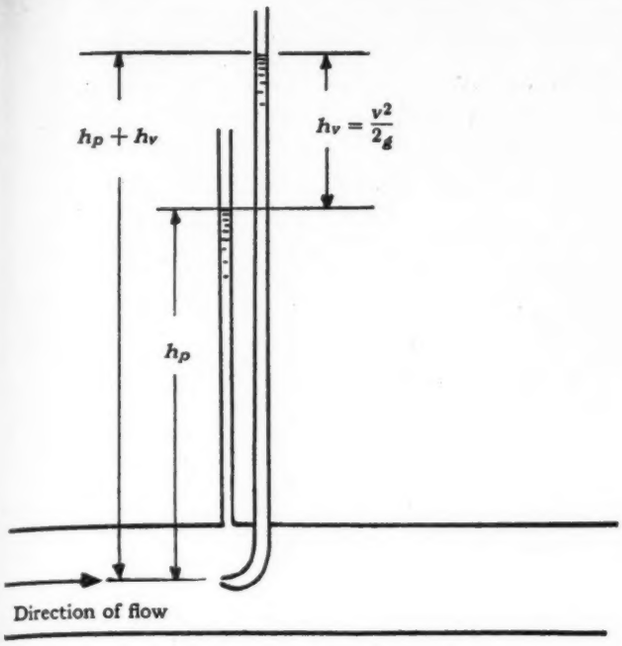


Fig. 37—Pitot Tube

difference in the height of the water in the two tubes is therefore equal to the velocity head, h_v.

Mercury columns or manometers may be used, instead of the water column, to determine the pressures.

In order to determine the discharge by use of a pitot tube, the cross section of the stream or pipe must be divided into one or more known areas, the velocity for each found, and hence the mean velocity of the entire cross section. The discharge is then found by multiplying the cross-sectional area by the mean velocity. In a straight length of pipe which extends upstream about 50 diameters from place of measurement without tees, valves, etc., the distribution of velocities is normal. Where normal distribution of velocities prevails, the ratio of mean velocity to center velocity (called the pipe coefficient) averages about 0.83.

Venturi Meters

The Venturi meter was invented by Clemens Herschel and was named by him for the inventor of the principle involved. It may be used to measure the discharge of water or other fluids contained in pipes which run full and under positive pressure.

The Venturi tube consists of a converging cone of steep taper, a diverging cone of more gradual taper, and a short cylindrical section called the throat, which connects the two cones at their smallest diameters. The essential parts of a Venturi meter are shown in Fig. 38. In this figure h_1 represents the pressure head in the pipe upstream for the Venturi meter, h_2 the pressure head at the throat, and h_3 the pressure head in the pipe downstream from the Venturi meter. The difference between h_1 and h_3 is hf and is the loss of head due to friction in the Venturi tube. The loss of head in a Venturi tube is usually quite small (see Table 21). Where the recovery of pressure is not important the converging cone may be very short or may even be omitted, forming a Venturi nozzle.

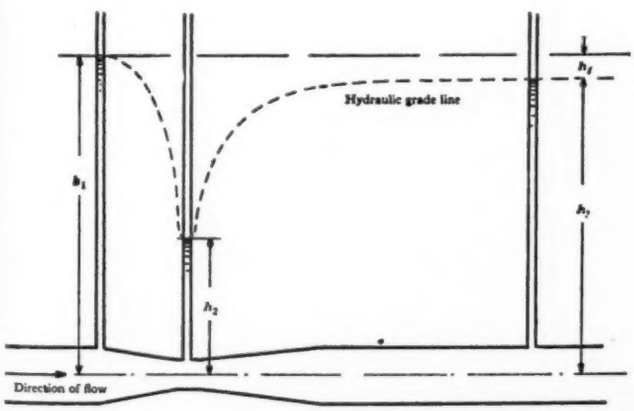


Fig. 38—Venturi Meter

Since the quantity of water flowing past any cross section of the tube is the same at any instant, the velocity at the small cross section of the throat will be greater than in the large cross section of the pipe upstream from the Venturi tube.

This greater velocity in the throat is obtained at the expense of the pressure head, so that h_2 is less than h_1. The dotted line in the figure represents the approximate hydraulic grade line and indicates the loss and recovery of pressure from h_1 to h_3.

The relation between the flow through a Venturi tube and the difference in pressure between the inlet and throat is given by the formula:

$$Q = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Inside diameter of throat of Venturi tube in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of inside of throat of tube in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
h_d = Differential head in feet of water = $h_1 - h_2$.
C_v = Discharge coefficient of Venturi tube which varies from about 0.95 to 0.995.

The pressure differences ($h_1 - h_2$) may be measured by a simple glass U-tube containing mercury. Commercial Venturi tubes are usually provided with two annular chambers connected by vents with the inlet and throat, respectively, to obtain correct average pressures at these points. Various types of indicating, recording and integrating meters may be obtained for use with commercial Venturi tubes.

Pipe Orifices

Orifices in diaphragms inserted between pairs of flanges in straight portions of pipe lines have been found to be reliable measuring devices. The diaphragms are usually of thin noncorrodible metal and the orifices are accurately machined to size and beveled on the downstream side to keep the working edge thin.

Fig. 39 shows the essential parts of such a device. Two piezometer tubes are attached to the line, one at a distance of

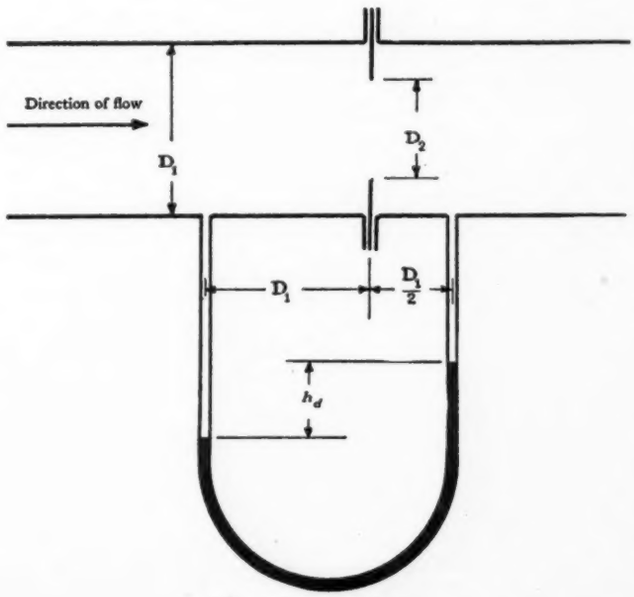


Fig. 39—Pipe Orifice

one pipe diameter upstream and the other one-half pipe diameter downstream from the plate. Either a differential gage, as shown in the figure, or open water columns may be used, depending upon the pressure. The rate of flow is a function of the differential pressure as indicated by the formula:

$$Q = C_o A_2 \sqrt{\frac{2ghd}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_o A_2 \sqrt{\frac{2ghd}{1-\left(\frac{D_2}{D_1}\right)}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Diameter of orifice in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of orifice in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
h_d = Differential head in feet of water = $h_1 - h_2$.
C_o = Discharge coefficient = about 0.606 for D_2/D_1 from 0.10 to 0.75.

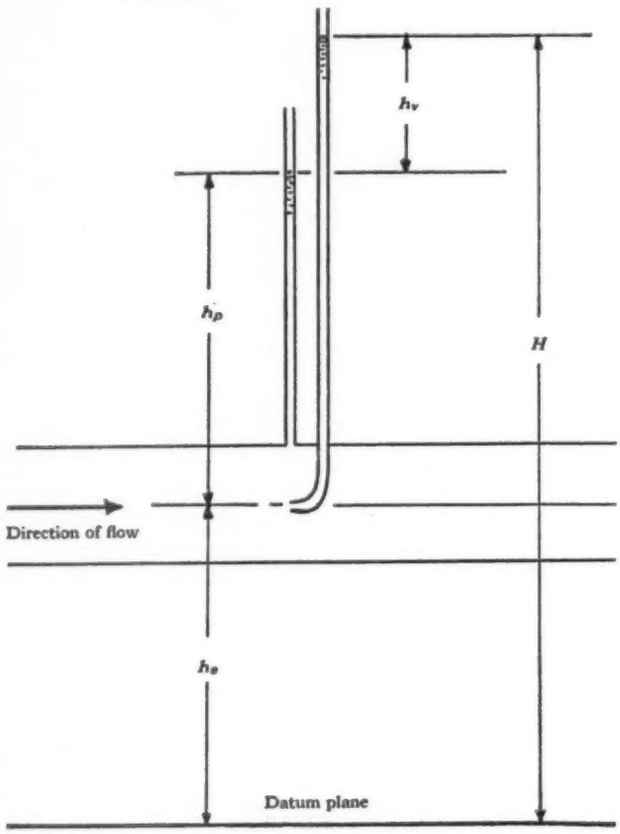


Fig. 40—Total Head

The orifice should be placed in a straight section of horizontal or vertical pipe and should be located as far as possible from bends, fittings, and valves. The diameter of the orifice should not be greater than 75 to 80 per cent of the inside diameter of the pipe. The loss of head in the pipe orifice is quite large and it is less reliable than the Venturi meter.

Water Power

The total available power of flowing water is given by the formula:

$$H.P. = \frac{QwH}{550} = 0.113472\,QH$$

where $H.P.$ = Horse Power.
Q = Discharge in cubic feet per second.
H = Total available head in feet.
w = Weight of one cubic foot of water (at 50° F. = 62.4096 pounds).

The total head may be made up of velocity head, pressure head, and potential head, or head due to actual height above the datum plane. Fig. 40 illustrates the three components of the total head.

The value of the velocity head is given by the expression:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Table 22
Horsepower for Various Heads of Water

Horse power for 1 cu. ft. of water per second under heads of 1 to 2,000 ft. Based on an efficiency of 80 per cent and weight of water at 50°F. = 62.4096 lb. per cubic foot.

(Horse power per cubic foot of water per second = $\frac{62.4096 \times 0.80 \times H}{550} = 0.0907776\,H$).

Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power
1	0.0907776	170	15.4322	420	38.1266	925	83.9693
2	.181555	180	16.3400	430	39.0344	950	86.2387
3	.272333	190	17.2477	440	39.9421	975	88.5082
4	.363110	200	18.1555	450	40.8499	1000	90.7776
5	.453888	210	19.0633	460	41.7577	1050	95.3165
6	.544666	220	19.9711	470	42.6655	1100	99.8554
7	.635443	230	20.8788	480	43.5732	1150	104.394
8	.726221	240	21.7866	490	44.4810	1200	108.933
9	.816998	250	22.6944	500	45.3888	1250	113.472
10	.907776	260	23.6022	525	47.6582	1300	118.011
20	1.81555	270	24.5100	550	49.9277	1350	122.550
30	2.72333	280	25.4177	575	52.1971	1400	127.089
40	3.63110	290	26.3255	600	54.4666	1450	131.628
50	4.53888	300	27.2333	625	56.7360	1500	136.166
60	5.44666	310	28.1411	650	59.0054	1550	140.705
70	6.35443	320	29.0488	675	61.2749	1600	145.244
80	7.26221	330	29.9566	700	63.5443	1650	149.783
90	8.16998	340	30.8644	725	65.8138	1700	154.322
100	9.07776	350	31.7722	750	68.0832	1750	158.861
110	9.98554	360	32.6799	775	70.3526	1800	163.400
120	10.8933	370	33.5877	800	72.6221	1850	167.939
130	11.8011	380	34.4955	825	74.8915	1900	172.477
140	12.7089	390	35.4033	850	77.1610	1950	177.016
150	13.6166	400	36.3110	875	79.4304	2000	181.555
160	14.5244	410	37.2188	900	81.6998	....	.....

Table 25—Pressure Equivalents

Units		Pounds per square inch	Pounds per square foot	Kilograms per square centimeter	Inches of mercury at 32° F.	Feet of water at 39.2° F.	Feet of water at 62° F.	Atmospheres
1 pound per square inch	=	1.	144.	0.0703067	2.0360	2.30671	2.30934	0.068044
1 pound per square foot	=	0.0069444	1.	0.0004882	0.014139	0.016019	0.016037	0.0004725
1 ounce per square inch	=	0.0625	9.	0.0043942	0.12725	0.144169	0.144334	0.0042528
1 kilogram per square centimeter	=	14.2234	2048.17	1.	28.9582	32.8092	32.8467	0.967820
1 kilogram per square meter	=	0.0014223	0.204817	0.0001	0.0028958	0.0032809	0.0032847	9.678×10^{-5}
1 inch of mercury at 32° F.	=	0.49117	70.7285	0.034533	1.	1.13299	1.13428	0.033421
1 inch of water at 39.2° F.	=	0.036127	5.20222	0.0025399	0.073552	0.083333	0.083428	0.0024582
1 inch of water at 62° F.	=	0.036085	5.19628	0.0025370	0.073468	0.083238	0.083333	0.0024554
1 foot of water at 39.2° F.	=	0.43352	62.4266	0.030479	0.88262	1.	1.00114	0.029498
1 foot of water at 62° F.	=	0.43302	62.3554	0.030444	0.88162	0.99886	1.	0.029465
1 atmosphere	=	14.6963	2116.27	1.03325	29.9210	33.9001	33.9388	1.

Table 26—Rate of Flow Equivalents

Units		Cubic feet per second	Cubic feet per minute	U. S. gallons per minute	U. S. gallons per 24 hours	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hours
1 cubic foot per second	=	1.	60.	448.831	646 317.	373.729	1698.98	0.082645	1.98347
1 cubic foot per minute	=	0.016667	1.	7.48052	10 771.9	6.22882	28.3163	0.0013774	0.033058
1 U. S. gallon per minute	=	0.0022280	0.13368	1.	1440.	0.83267	3.78533	0.0001841	0.0044192
1 U. S. gallon per 24 hours	=	1.547×10^{-6}	9.283×10^{-5}	0.0006944	1.	0.0005782	0.0026287	1.279×10^{-7}	3.069×10^{-6}
1 British Imperial gallon per minute	=	0.0026757	0.16054	1.20095	1729.37	1.	4.54601	0.0002211	0.0053072
1 liter per minute	=	0.0005886	0.035315	0.26418	380.416	0.21997	1.	4.864×10^{-5}	0.001167
1 acre-foot per hour	=	12.1	726.	5430.86	7 820 434.	4522.13	20 557.6	1.	24.
1 acre-foot per 24 hours	=	0.50417	30.25	226.286	325 851.	188.422	856.567	0.041667	1.

Table 26—Volume and Capacity Equivalents

Units		United States gallons	British Imperial gallons	Liters	Cubic feet	Cubic inches	Acre-feet
1 United States gallon	=	1.	0.832672	3.78533	0.133681	231.	3.069×10^{-6}
1 British Imperial gallon	=	1.20095	1.	4.54601	0.160544	277.420	3.686×10^{-6}
1 liter	=	0.264177	0.219973	1.	0.035315	61.0250	8.107×10^{-7}
1 cubic foot	=	7.48052	6.22882	28.3163	1.	1728.	2.296×10^{-5}
1 cubic inch	=	4.329×10^{-3}	3.605×10^{-3}	0.016387	5.787×10^{-4}	1.	1.329×10^{-8}
1 acre-foot	=	325 851.	271 328.	1 233 456.	43 560.	75 271 680.	1.
1 inch deep on 1 acre	=	27 154.3	22 610.6	102 788.	3 630.	6 272 640.	0.083333
1 inch deep on 1 square mile	=	17 378 743.	14 470 801.	65 784 344.	2 323 200.	4 014 489 600.	53.3333
1 meter deep on 1 hectare	=	2 641 705.	2 199 675.	9 999 734.	353 145.	610 233 780.	8.10708
1 centimeter deep on 1 square meter	=	2.64171	2.19967	9.99973	0.353145	610.234	8.107×10^{-6}
1 pound of water at 39.2° F.	=	0.11983	0.099778	0.45359	0.016019	27.6805	3.677×10^{-7}
1 pound of water at 50° F.	=	0.11986	0.099806	0.45372	0.016023	27.6880	3.678×10^{-7}
1 pound of water at 62° F.	=	0.11997	0.099892	0.45411	0.016037	27.7121	3.682×10^{-7}
1 U. S. gallon per minute for 24 hours	=	1440.	1199.05	5450.88	192.5	332 640.	0.0044192
1 cubic foot per minute for 24 hours	=	10 771.9	8 969.50	40 775.4	1440.	2 488 320.	0.033058

The pressure head is given by the expression:

$$h_p = \frac{P}{w}$$

where h_p = Pressure head in feet.
P = Pressure in pounds per square foot.

The potential head or head due to height above the datum plane is h_e feet.

The total head, H, is therefore:

$$H = h_v + h_p + h_e$$

or

$$H = \frac{v_2}{2g} + \frac{P}{w} + h_e$$

In any stream flowing steadily without friction, the total head, and the total amount of energy per unit of water, is the same at every point in the path of flow. This principle, which is in reality the law of conservation of energy applied to flowing water, is known as Bernoulli's Theorem.

Table 22 gives the horse power for one cubic foot of water per second, under heads of 1 to 2000 feet, based on an efficiency of 80 per cent. The method of using this table is illustrated by the following example:

Determine the horse power which can be developed by a flow of 60 cubic feet per second under a head of 200 feet.

From the table the horse power for a discharge of one cubic foot per second under 200 feet head is found to be 18.1555. The horse power for a discharge of 60 cubic feet per second under 200 feet head is then:

$$60 \times 18.1555 = 1089.33 \text{ horse power.}$$

When the exact head is not given in the table the horse power may be found by multiplying the horse power for one foot head and one cubic foot per second (0.0907776) by the head in feet and then by the discharge in cubic feet per second. For example, the horse power which can be developed by a discharge of 45 cubic feet per second under a head of 105 feet will be:

$$0.0907776 \times 105 \times 45 = 428.92 \text{ horse power.}$$

TABLE I.—FLOW OF WATER THROUGH STD. W.I. OR STEEL PIPES IN FAIR CONDITION

NOTE: For old or rough pipes add 25% to the pressure drop given in the table. Figures in bold face type are for the usually allowed range of velocities, 2.0 to 10.0 ft. per sec. Figures marked thus * are for 5.0 ft. per sec. velocity (approx.).

Discharge Gallons Per Min.	PRESSURE DROP, POUNDS PER SQ. IN. PER 1000 FT. OF PIPE (1.0 Lb. per Sq. In. = 2.30 Ft. of Water)									
	1″									
1	.55	1¼″								
2	2.0	.50	1½″							
3	4.25	1.08	.50							
4	7.3	1.85	.86	2″						
5	11.1	2.81	1.31							
6	15.4	3.94	1.82	.52	2½″					
8	25.3	6.70	3.11	.88						
10	40.0	10.2	4.70	1.34	.55	3″				
15	85.0*	21.8	10.1	2.85	1.18		3½″			
20	145	36.8*	17.1	4.85	2.00	.68				
25		56.0	26.0	7.32	3.04	1.02	.49	4″		
30		78.5	36.4*	10.4	4.26	1.44	.69			
35		100	48.3	13.7	5.14	1.92	.93	.49	4½″	
40			62.5	17.6	7.29	2.45	1.18	.63		
45			78.0	22.1	9.12	3.08	1.49	.79	.45	
50			94.0	26.7*	11.0	3.72	1.80	.96	.54	5″
60				37.5	15.5	5.20	2.54	1.24	.77	
70				51.8	21.4	7.25	3.48	1.86	1.06	.57
80	6″			63.8	26.4*	8.90	4.33	2.30	1.32	.70
90				79.1	32.8	11.1	5.31	2.86	1.63	.87
100	.45			96.8	40.0	13.5	7.78	3.47	2.37	1.06
125	.68				60.6	20.5*	9.90	5.28	3.02	1.62
150	.95				65.2	28.8	13.9*	7.40	4.24	2.28
175	1.26	8″			86.6	39.0	18.4	9.80	5.60	3.00
200	1.62					49.0	23.6	12.6*	7.40	3.85
225	2.00	.51				60.6	29.3	15.6	8.90	4.76
250	2.45	.63				74.1	35.8	19.0	10.9*	5.85
275	2.93	.74				88.2	42.6	22.8	13.0	6.92
300	3.44	.87				104	50.2	26.8	15.3	8.20*
325	3.98	1.02					58.0	31.0	17.8	9.55
350	4 55	1.12	10″				66.8	35.7	20.3	10.9
375	5.17	1.32					75.2	40.3	23.0	12.4
400	5 85	1.49	.48				85.3	45.5	26.2	14.0
425	6.53	1.67	.53				95.3	50.7	29.1	15.6
450	7.28*	1.85	.59				108	56.8	32.8	17.4
475	8.07	2.05	.66				118	62.8	35.8	19.2
500	8.90	2.28	.73					69.3	39.6	21.3
550	10.6	2.71	.87	12″				82.7	47.3	25.4
600	12.5	3.18	1.02					97.0	55.4	29.8
650	14.4	3.67	1.18	.48				112	64.0	34.5
700	16.6	4.23	1.36	.55					74.0	39.7
750	19.0	4.80	1.54	.63	14″				84.0	45.0
800	21.3	5.41*	1.73	.70					94.5	50.8
850	23.7	6.05	1.94	.79	.48				106	56.7
900	26.4	6.72	2.16	.87	.53					62.8
950	69.2	7.45	2.38	.96	.59					69.6
1,000	32.3	8.18	2.63	1.06	.65	16″				76.8
1,100	38.6	9.82	3.15	1.27	.78					91.8
1,200	45.1	11.6	3.64*	1.50	.91	.45				108
1,300	52.5	13.4	4.30	1.74	1.06	.52				
1,400	60.0	15.4	4.88	1.99	1.22	.60				
1,500	68.8	17.5	5.59	2.28	1.39	.69	18″			
1,600	77.1	19.7	6.29	2.56	1.56	.77				
1,800	96.1	24.5	7.85	3.19*	1.93	.96	.52			
2.000	117	29.9	9.57	3.86	2.37*	1.17*	.63	20″		
2.500		45.1	14.5	5.88	3.58	1.77	.96			
3,000		63.2	20.4	8.23	5.02	2.49*	1.35	.55	24″	
3.500		84.0	27.2	10.9	6.68	3.31	1.79*	.78		
4,000		108	34.7	14.1	8.52	4.22	2.29	1.04	.51	
4,500			43.2	17.4	10.6	5.22	2.85	1.32*	.64	
5,000			52.3	21.3	12.9	6.40	3.48	1.64	.79	
6,000			73.1	29.8	18.2	8.98	4.85	2.00	1.09	
7,000			98.0	39.6	23.2	11.9	6.47	3.74	1.45*	
8,000			125	50.9	30.9	15.2	8.25	4.76	1.86	
9,000				62.8	38.3	19.0	10.3	5.90	2.20	
10,000				77.0	46.7	23.4	12.2	7.22	2.92	
12,000				108	66.0	32.7	17.7	10.2	3.96	
14,000					87.5	43.3	23.6	13.5	4.51	
15,000					99.4	49.5	26.7	15.3	5.99	
16,000					112	55.4	30.2	17.4	6.76	
18,000						69.2	37.6	21.6	8.45	
20,000						84.8	45.6	26.4	10.3	
22,000						100	54.0	31.2	12.2	
24,000							63.8	36.8	14.3	
25,000							69.0	39.6	15.4	
30,000							96.2	55.5	21.6	
35,000							129	74.2	28.8	
40,000								95.3	37.0	
45,000								119	45.9	
50,000									56.0	
55,000									66.8	
60,000									78.2	

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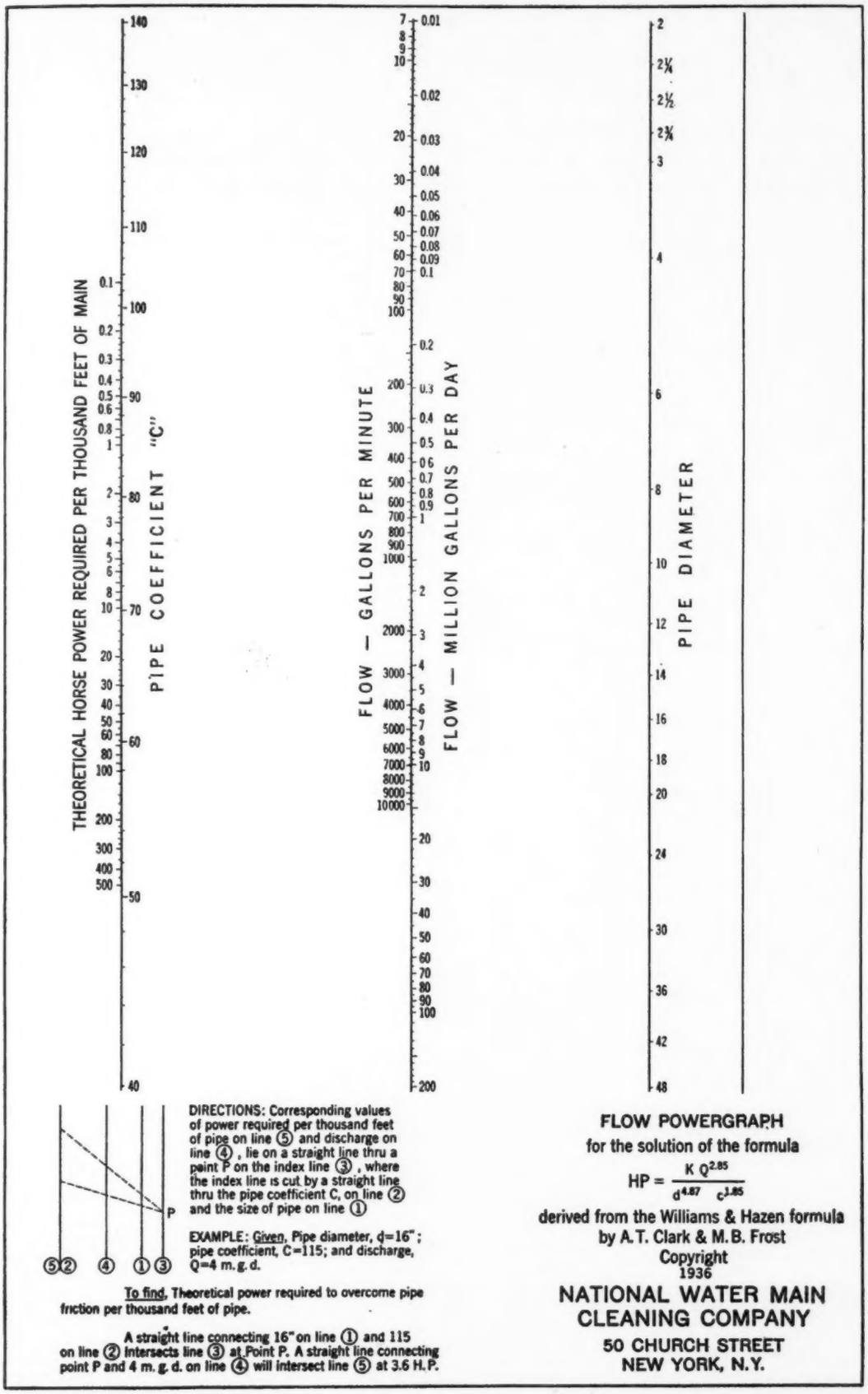
Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
⑤ ② ④ ① ③
P
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line ① and 115 on line ② intersects line ③ at Point P. A straight line connecting point P and 4 m. g. d. on line ④ will intersect line ⑤ at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
$HP = \frac{K\,Q^{2.85}}{d^{4.87}\ c^{1.85}}$
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

This Highly Useful Gift Was Devised by Arthur T. Clark of Barrett & Co. and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to Determine Condition of Pipe Lines in Service. (Copies on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF WATER*

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves and fittings becomes

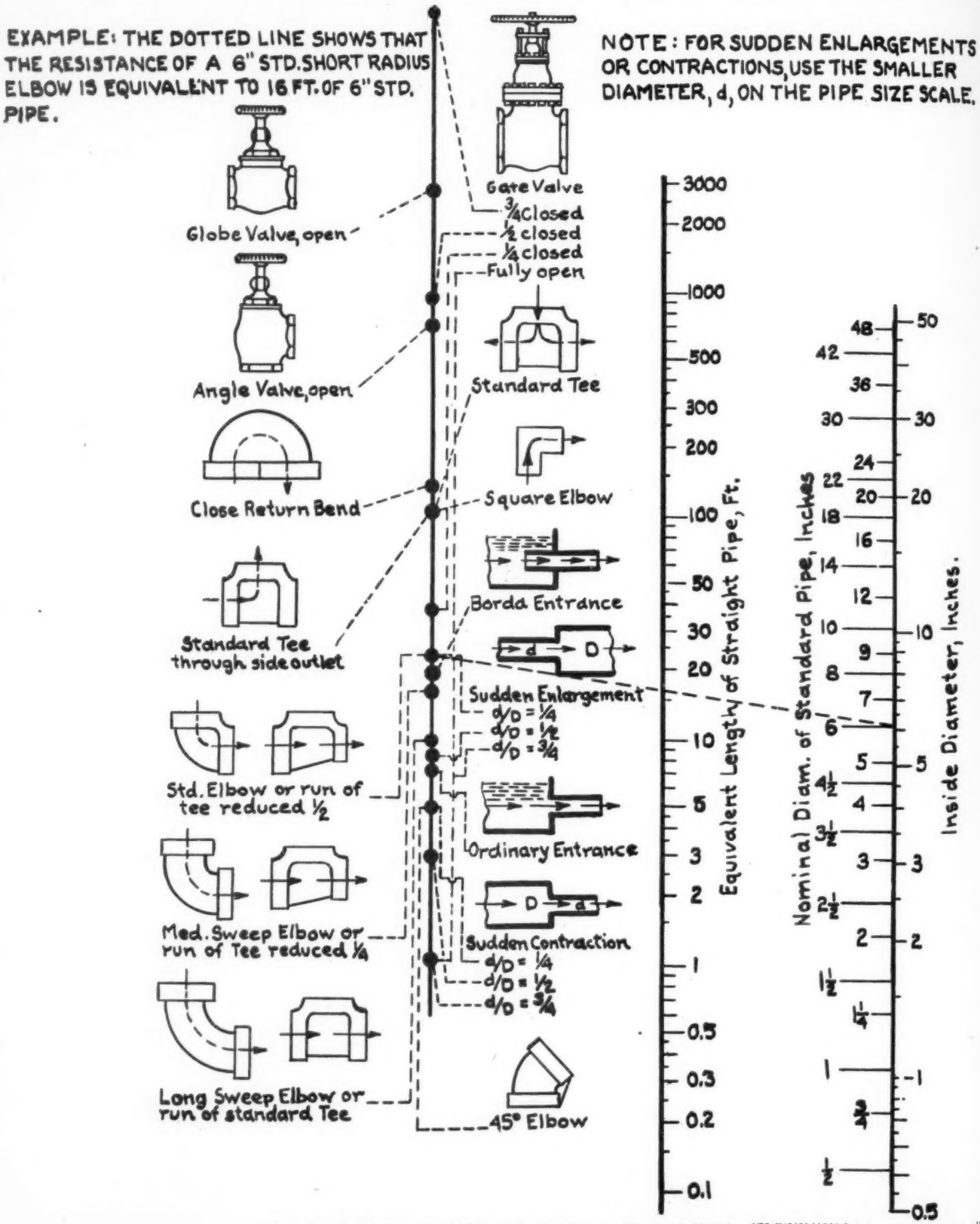


Fig. 16—Resistance of Valves and Fittings to Flow of Fluids

a major item in the total pressure drop value.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines" published in Vol. 42, 1920, of the Transactions of the American Society of Mechanical Engineers. Recently, tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

Realizing the need for definite data covering this subject, Crane Co. has recently conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.) from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual. This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows in "The Friction of Water in Pipes and Fittings" by F. E. Giesecke, University of Texas Bulletin No. 1759.

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, Fig. 16, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

*From Crane Co.'s "Engineering Data on Flow of Fluids in Pipes"—Technical Bulletin No. 405—1935. Parts dealing with steam pressure losses have been omitted.—Ed.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the following coefficients of

$$H_1 = k\frac{V^2}{2g}$$

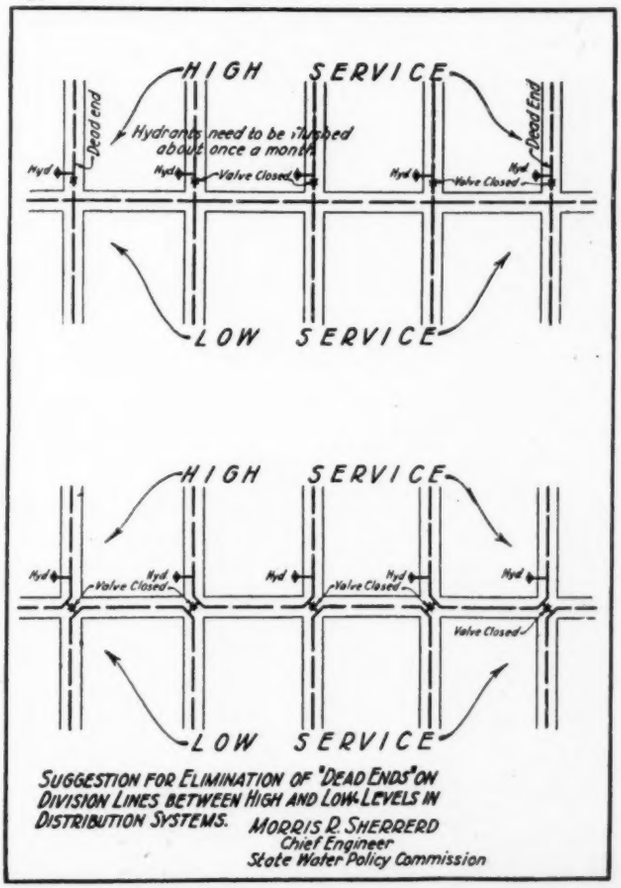
H_1 = Loss of head in ft.
k = Coefficient
V = Vel. in ft. per sec.
2g = 64.4

Type	*Coefficient*	*Authority*
Globe valves	10	Crane Tests
Angle Valve	5	Crane Tests
Return Bend	2.2	
Tee	1.8	Giesecke & Bladgett—Texas College
Short Radius Elbow	.9	Giesecke & Bladgett—Texas College
Med. Radius Elbow	.75	& Crane tests
Long Radius Elbow	.60	Bulletin No. 2712—U. of Texas.
Gate Valve (Open)	.19	Bulletin No. 252—U. of Wis. (Av.)
¼ Closed	1.15	Bulletin No. 252—U. of Wis. (Av.)
½ Closed	5.6	Bulletin No. 252—U. of Wis. (Av.)
¾ Closed	24.0	Bulletin No. 252—U. of Wis. (Av.)
Borda Entrance	.83	"Hydraulic" Daugherty (Average)
Sudden Enlargement		
d/D — ¼	.92	"Hydraulics" Daugherty
d/D — ½	.56	"Hydraulics" Daugherty
d/D — ¾	.19	"Hydraulics" Daugherty
Ordinary Entrance	.5	"Hydraulics" Daugherty
Sudden Contraction		
4/D = ¼	.42	"Hydraulics" Daugherty
d/D = ½	.33	"Hydraulics" Daugherty
d/D = ¾	.19	"Hydraulics" Daugherty
45° Elbow	.42	Bulletin No. 2712U. of Texas

One Method of Eliminating Dead Ends

A means of eliminating dead ends of water mains where there are two types of water service, has been developed by Morris R. Sherrerd, Chief Engineer, New Jersey State Water Policy Commission.

The lower part of the illustration shows how by having a short gated connection between the two services, and by running the main around the block or square without using a cross fitting, dead ends are eliminated.



SUGGESTION FOR ELIMINATION OF "DEAD ENDS" ON DIVISION LINES BETWEEN HIGH AND LOW LEVELS IN DISTRIBUTION SYSTEMS. MORRIS R. SHERRERD Chief Engineer State Water Policy Commission

PUMPS

DEFINITIONS AND VALUES

(Adopted by the Hydraulic Society)

Efficiency, Hydraulic (Symbol e_h).—The ratio of the useful power delivered in the water at the point of discharge where measured to the power delivered to the water by the impeller at the point of exit from the impeller.

Efficiency, Mechanical (Symbol e_m).—The ratio of the water horsepower to the horsepower required to drive the pump.

Efficiency, Overall (Symbol e).—Comprises all the losses in the pump and the driver, and indicates the economy of the entire unit.

Head, Total Dynamic (Symbol T.D.H.).—Total dynamic head is the vertical distance between the source of supply and point of discharge when pumping required capacity, plus friction entrance and exit losses.

Total dynamic head, as determined on test, where suction lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance betwen point of attachment of mercury column and center of gauge, plus excess, if any, of velocity head of discharge over velocity head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total dynamic head, as determined on test, where suction head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge) plus excess, if any, of velocity head of discharge over velocity head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head is the total dynamic head minus dynamic suction lift, or plus dynamic suction head.

Head, Static (Symbol H_s).—Static head is the vertical distance between the free level of the source of supply and to the point of free discharge, or to the level of the free surface of the discharge water.

Head, Velocity (Symbol H_v).—The velocity head (sometimes called "Head due to Velocity") of water moving with a given velocity is the equivalent head through which it would have to fall to acquire the same velocity; or, in other words, the head necessary merely to accelerate the water. Knowing the velocity, we can readily figure the velocity head from the simple formula:

$$h = \frac{V^2}{2g}$$

in which "g" is acceleration due to gravity, or 32.16 feet per second; or, knowing the head, we can transpose the formula to $V = \sqrt{2gh}$, and thus obtain the velocity.

The velocity head is a factor both in figuring the total head from construction data and testing.

When estimating the total dynamic head of an installation, the head equivalent to the velocity of the water leaving the end of the discharge pipe line must be added to the static and friction head.

When testing a pump, certain velocity head corrections must be made, depending on the average velocity at the point where pressure readings are taken. The customary method of testing is to use a mercury column for obtaining the suction lift and a gauge to indicate the discharge or suction head, with gauge connections at or close to the pump openings.

The mercury column at the suction will show the dynamic suction head at the point of gauge connection. Included in this dynamic suction head is the velocity head as represented by the average velocity at that point.

The discharge gauge will show the dynamic pressure head at the point of gauge connection.

The sum of the two gauge readings, corrected to the same elevation, will give the total dynamic head produced by the pump, provided water flows at the same average velocity at the point of attachment of suction gauge as of discharge gauge. This condition will exist when suction and discharge openings are of equal size.

If the discharge pipe is of smaller diameter than the suction pipe, which is often the case, then it will be necessary to add to the total head, as shown by the gauges, the difference in velocity head between that of the discharge and that of the suction pipe at the point where gauges are connected.

If the discharge pipe is larger than the suction pipe, the difference in velocity head must be subtracted from the total head.

Velocity ft. per second	1	2	3	4	5	6	7
Velocity head in ft.	.02	.06	.14	.25	.39	.56	.76
Velocity ft. per second	8	8.5	9	9.5	10	10.5	
Velocity head in ft.	1.0	1.12	1.25	1.4	1.55	1.7	
Velocity ft. per second	11	11.5	12	13	14	15	
Velocity head in ft.	1.87	2.05	2.24	2.62	3.05	3.5	

Horsepower, Brake (Symbol b-hp.).—The actual horsepower required at the pump shaft to drive the pump $= \frac{\text{w-hp}}{e_m}$.

Brake horsepower is not applicable to direct-acting steam pumps.

Horsepower, Indicated (Symbol i-hp.).—The horsepower developed in the steam or liquid end calculated from indicator cards.

Suction Head (sometimes called head on suction) exists when the pressure measured at the suction nozzle and corrected to the center line of the pump is above atmospheric pressure.

Suction Head Dynamic, where static suction head exists, is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus velocity head. minus entrance, friction and velocity losses; but not minus internal pump losses.

Suction head dynamic, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center line of pump. Suction head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to suction will prevail.

Suction Head Static exists when the source of supply is above the center of pump and is the vertical distance from the free level of the source of supply to center of pump.

Suction Lift.—Suction lift exists when the suction measured at the pump nozzle and corrected to the center line of the pump is below atmospheric pressure.

Suction Lift Dynamic, where static suction lift exists, is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus velocity head, plus entrance, friction and velocity losses, but not including internal pump losses; where static suction head exists but where the losses exceed the static suction head the dynamic suction lift is the sum of the velocity head, entrance, friction and velocity losses, *minus* the static suction head, but not including internal pump losses.

Suction lift dynamic, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Lift Static exists when the source of supply is below the center of pump and is the vertical distance from the free level of source of supply to center of pump.

Viscosity is that property of a liquid which resists any force tending to produce flow. Viscosity is a property independent of specific gravity.

SOME NOTES ON ELECTRICALLY DRIVEN CENTRIFUGAL PUMPS

By HOMER E. BECKWITH*

In the past few years there has been a rapid change from steam to electrically driven centrifugal pumps, especially in the smaller water works plants. The many advantages of electric power are coming to be more and more realized, but unfortunately in many cases a full knowledge of the nature of centrifugal pumps does not seem to have accompanied their adoption. It is economy of the highest order, therefore, to secure the advice of a competent engineer before purchasing any centrifugal pumping equipment.

Centrifugal pumps are designed to operate under fixed conditions, and any appreciable change from design conditions will result in decreased efficiency.

Installations have been found where pumps were working against more than the design head, or against less than the design head, or with the discharge or suction partly closed to control the rate of discharge. Or pumps have been installed without knowledge that the friction head is a part of the total head against which the pump operates. All of these factors adversely affect the performance of the equipment to such an extent that the cost of efficient machinery is often wasted every few months through inefficient operation. Also, accidents can occur to equipment in operation which decreases its efficiency.

For some time the writer has felt that some simple method should be available to the average water works operator whereby he could check up on his pumps. Table 1 was worked up for personal use, but may prove to be of interest. A slide rule was used in its preparation, but it should be accurate to a fraction of 1 per cent. With this table, it is believed that the work of securing overall wire to water efficiencies will be reduced to a minimum. Table 1 shows the number of gallons pumped per kilowatt hour against a given head, assuming the motor and pumps have efficiencies of 100 per cent. A rough check can be made by dividing a month's pumpage in gallons by the kilowatt hours consumed. This gives the number of gallons pumped per kilowatt hour. With the pump running, determine the average total head in feet (including suction) against which the pump works. From the table secure the number of gallons which would have been pumped at the head if the installation were 100 per cent efficient. Divide the number of gallons actually pumped per kilowatt hour by the theoretical value given in the table. This gives the overall wire to water efficiency of the installation. To illustrate:

Assume a monthly pumpage of 18,620,000 gals., a total head of 200 ft., and a power consumption of 20,000 kilowatt hours. Dividing 18,620,000 by 20,000 we get 931 gals. per kilowatt hour. For 100 per cent efficiency the tables indicate that the discharge would be 1,592 gals. against a head of 200 ft. Dividing the actual discharge per kilowatt hour by the theoretical value we have: $\frac{931}{1,592} = 58.5$ per cent overall efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or other convenient period of time. During this period measure the output of the pump with a pitometer, or any other suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for 10 or 20 minutes the rate of power input can be closely ascertained. Or the power company might measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, this latter method is the only feasible one.

To enter the tables, the total head in feet must be secured. If the pressure gauge reads in pounds, transfer the pressure to feet by multiplying the pounds of pressure by 2.31. The suction will probably be expressed in inches of mercury. Change this to feet of water by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the addition of:

Discharge pressure, in feet .....
Suction, in feet .....
Vertical distance pressure gauge (Is above point of suction measurement), feet .....

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump works against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value secured from the table for the head against which the pump worked. This gives the overall wire to water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

K.W. input to motor 90.0
Rate of discharge.....51,480 gal. per hour
Number of gallons delivered per k.w.h..... 572

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	705
4	79,560	54	5,894	104	3,060	154	2,067	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	685
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	722	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	636

*The Pitometer Co., New York City.
[1]From WATER WORKS AND SEWERAGE.

Pressure	146 lb. or 337 ft.
Suction	15 in. or 17 ft.
Difference in gauge elevation	1 ft. 1 ft.
Total head	355 ft.
Theoretical discharge 355 ft. head (tables)	897 gal.
Overall efficiency	$\frac{572}{897}$ = 64 per cent

Provided a suction gauge is not available an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about one foot for loss in bends, etc.

Results of Checking Efficiency

The solution of each instance of inefficient operation is a problem in itself. No hard and fast rule for procedure can be given. In the case cited of obsolete design, the economical procedure was to replace the pump with one of modern design, keeping the old unit as a standby. In other instances, a change in the impeller will often return the pump to high efficiency. In one case, where a multiple stage pump was working against a high head, it was found that its inefficiency was caused by a defective gasket between the upper and lower parts of the pump case. This permitted the water to flow back from the higher to the lower stages, thereby decreasing both the rate of discharge and the efficiency. A new gasket was all that was necessary to solve the difficulty. In another instance, it was found that some of the ports had become plugged with wood, probably when a filter bed had broken three years previously. At least once, an impeller was found loose on the shaft.

About two years ago, an instance was uncovered where an apparent inefficiency was due to the power meter being set high. As soon as the test figures were in, the striking thing was not so much the low efficiency indicated, as the fact that the motor was apparently taking power at a rate which would have caused it to "burn up" from over-loading.

This list could be prolonged almost indefinitely, but it is believed that enough illustrations have been given to show the value of continuous checks. Many progressive operators show on their monthly or weekly reports the number of gallons pumped for the period for each kilowatt hour of power consumed. This is a splendid practice. Whenever our company, in making these tests, has found a low efficiency indicated, our experience has shown that the power companies and the pump manufacturers are most willing to cooperate in restoring the plant to efficient operation.

Assuming that the motor is about 90 per cent efficient, the following overall wire to water efficiencies may be expected from centrifugal pumps of good design:

g. p. m.	Per cent
200	49
400	54
600	58
800	60
1000	63
1500	67

More expensive pumps of best design will often show values of three to five per cent higher than the above figures.

In order to illustrate how the table can be used to compute probable savings to result from the substitution of a more efficient unit for an existing inefficient one, let us assume that 1,000 g.p.m. are being pumped against a total head of 200 ft., and a discharge of only 796 gal. per k.w.h. is secured. This gives us $\frac{796}{1592}$ = 50 per cent efficiency. Should this installation be replaced by one capable of an overall efficiency of 65 per cent, we would get 1,592 × 65 per cent = 1,035 gal. per k.w.h.

With an assumed monthly pumpage of 30,000,000 gal., it would require, with the original installation, $\frac{30{,}000{,}000}{796}$ = 37,676 k.w.h. to pump the water.

With the proposed more efficient installation it would require $\frac{30{,}000{,}000}{1{,}035}$ = 28,986 k.w.h.

This is a saving of 8,690 k.w.h., or 23 per cent, in the actual power consumption. There is also a similar decrease in the demand rate. The pumping rate of 1,000 g.p.m. equals 60,000 g.p.m.

$$\frac{60{,}000}{796} = 75 \text{ k.w. demand rate}$$

and

$$\frac{60{,}000}{1{,}035} = 58 \text{ k.w. demand rate.}$$

This is a decrease of 17 k.w. or 23 per cent in the demand rate. Both the demand rate and the actual consumption of power are therefore decreased in the same proportion. If the power cost averages 2 ct. per k.w.h., the reduction amounts to 8,690 × 0.02 = $173.80 per month, or $2,085.60 per year.

A word of warning may not be amiss here. While the large pumps are more efficient than the smaller ones, pumps larger than actually required should not usually be used. Often the additional friction loss due to higher velocity will offset the increased efficiency, and the higher demand charges will boost the total bill considerably.

Assume an installation which consumes 12,000 k.w.h. per month and which has a demand schedule as follows:

5,000 k.w.h. @ 0.030c	$150.00
5,000 k.w.h. @ 0.026c	130.00
2,000 k.w.h. @ 0.012c	24.00
Total	$304.00

If we use a smaller installation with half this demand rate we might use 13,000 k.w.h. per month to pump the same amount of water, but the total bill would be less:

2,500 k.w.h. @ 0.030c	$ 75.00
2,500 k.w.h. @ 0.026c	65.00
8,000 k.w.h. @ 0.012c	96.00
Total	$236.00

This is a saving of $68.00 per month although more power is actually consumed. And, after all, the object in securing increased efficiency is to pump more water per dollar.

Measuring Output of Water

Table I previously given has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the same period. If a curve for the pump is not available and if the manufacturer cannot supply one, approximate results can be obtained by using the efficiencies previously given in this paper. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table 1 indicates the discharge would be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 × 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 × 931 or 18,620,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available. As a matter of fact, in one instance where this method was used to check the master meter, it was found that it would have been impossible for the pump to have delivered the water shown on the master meter unless the installation had an efficiency of about 125 per cent. This, of course, would be impossible. Whenever a pump installation gives an efficiency over 100 per cent, the secret of perpetual motion will have been discovered. In the case just cited, the master meter was about 100 per cent fast.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

S. R. DRESSER MANUFACTURING COMPANY

Bradford, Pa.

PRODUCTS TO HELP YOU *with your pipe-joint problems!*

General—The pipe couplings and pipe-line repair products described below have been used for 46 years on many of the country's largest water and sewage lines. (*Example*: 40-mile, 60" water line at Birmingham, Ala.)

Pipe-Joint Advisory Service—Recommendations without obligation will be furnished by Dresser Laboratories for the solution of unusual pipe-joint problems on receipt of necessary details, including: service (water, air, sludge, etc.), maximum working pressure, description of job, temperature range, etc., and the outside diameter, thickness, and kind of pipe, plus working sketches wherever possible.

DRESSER STYLE 38 COUPLINGS

Fig. 164d. Style 38 Steel Coupling 12" I.D.). Joins plain-end steel (and cast-iron) pipe.

Purpose—The Dresser Coupling is a "factory-made" pipe joint, which (when simply *assembled* on plain-end pipe) makes a *flexible*, permanently tight connection.

Description — Each standard Style 38 Steel Coupling is made up of one middle ring, two followers, two *resilient*, rubber gaskets, and a number of bolts (see cross-section below).

Advantages of the Dresser Coupling Are—(1) *Permanent Tightness* —confirmed by *millions* of field installations. (2) *Flexibility* —for absorbing pipe movements, expansion, settling, curves, etc. (3) *Simplicity*—unskilled labor, using only a wrench, can quickly install—or disconnect. (4) *Strength* —ample to hold safely any specified working pressure. (5) *Economy*—the only joint that insures *true* economy throughout its life.

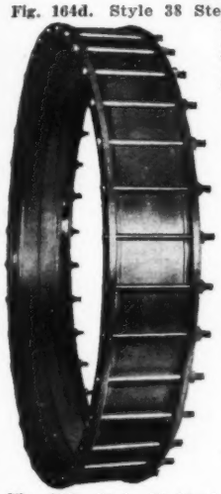


Fig. 166. Style 38 Steel Coupling (60" I.D.) for joining plain-end, large-diameter pipe above 24".

Sizes Available—Style 38 Couplings are made for all standard and special sizes, as well as all kinds of *plain-end* pipe. Size range: ⅜" to largest pipe made.

How to Order—When ordering, or asking for quotations on Style 38 Couplings, state: (1) quantity; (2) style number; (3) nominal size and outside diameter of pipe; (4) kind of pipe (steel, cast-iron, etc.); (5) working pressure; and (6) service (water, air, sludge, etc.). (On *special* orders, give the foregoing, plus details listed above under "Pipe-Joint Advisory Service.")

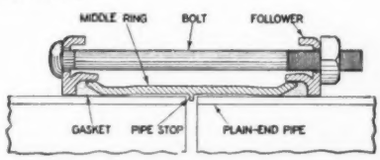


Fig. 165. Longitudinal section through a Style 38 Coupling (of typical size).

Fig. 168b. Style 38 Steel Coupling (5⅝" Cas.) for joining plain-end, light-wall steel pipe.

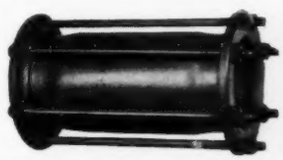


Fig. 195b. Style 40 Long Sleeve (6" I.D.). Is like Style 38 except has longer body to span variations in space between pipe ends.

DRESSER STYLE 53 COUPLINGS

Fig. 174b. Style 53 Cast Coupling (12" C.I.P.). For use with plain-end, cast-iron pipe under corrosive conditions. Similar to Style 38, except of cast material. Sizes available: 2" to 30" incl. (An alternate for these and larger sizes is Style 38 Steel Coupling for cast-iron pipe). Standard steel bolts, either galvanized or cadmium-plated, are regularly supplied with Style 53—though cast bolts can also be furnished.

DRESSER STYLE 65 FITTINGS

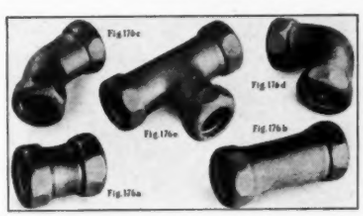
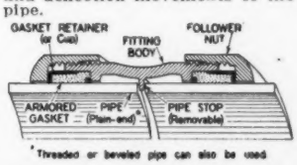


Fig. 176. Style 65 Fittings join plain-end, standard steel pipe. Shown are (all 1¼" I.D.): Style 65 Coupling (Fig. 176a); Style 65A Long Coupling (Fig. 176b); Style 65, 45° Ell (Fig. 176c); Style 65, 90° Ell (Fig. 176d); and Style 65 Tee (Fig. 176e).

Working Principle of Style 65—Threaded follower nuts on each end of fitting, when tightened with an ordinary wrench, cause *resilient* gaskets to compress tightly around ends of the pipe, effectively sealing in the contents of the line under all conditions. Resulting joint is permanently tight, yet flexible enough to absorb and cushion safely all vibration, expansion, contraction, and deflection movements of the pipe.

Purpose—Style 65 Fittings are *self-contained, flexible* pipe joints recommended for: (1) Water lines. (2) Hot-water lines. (3) Air lines. (4) Sewage lines of all kinds.

No Pipe Threading—Style 65 Fittings come completely assembled and may be installed in a moment with only a wrench. Just loosen nuts, slip in plain-end pipe, tighten with wrench. Result—a permanently tight, *flexible* pipe joint that acts as a union and makes unnecessary exact lengths of pipe.



—and here's information to help you with your repair problems, too:

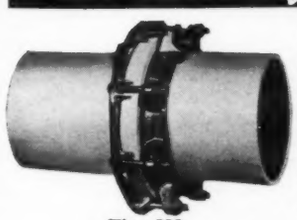


Fig. 238

Style 60 Bell-Joint Clamp (12" C.I.P.). Repairs and prevents leaks in bell joints. Readily adjusted to variations in bell and spigot diameters.

Fig. 266

Style 57 Cast Split Sleeve (12" C.I.P.). Encloses and permanently repairs splits and holes up to 8" long in straight run of pipe.

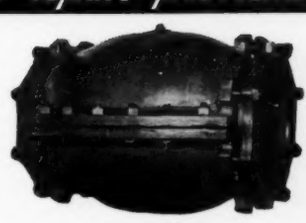


Fig. 268

Style 26 Cast Split Sleeve (12" C.I.P.). Encloses and permanently repairs broken or split bell joints.

S. R. DRESSER MFG. COMPANY, BRADFORD, PA.

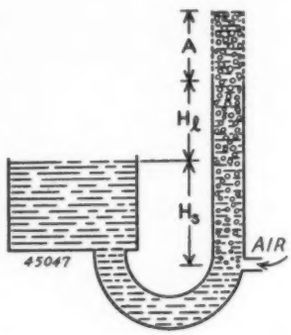
In Canada: **Dresser Mfg. Company, Ltd., 60 Front St., W., Toronto, Ont.**

• • Write on your business letterhead for our Pipe-Joint Handbook No. 36!

PUMPING BY AIR LIFT*

Principle

The method of pumping with compressed air can be illustrated by the drawing at the right.



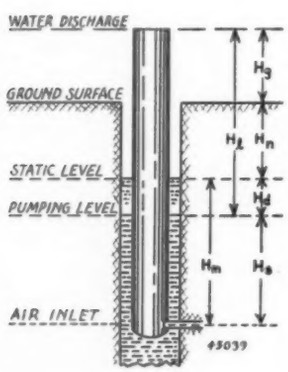
If the tank is filled with water, it is clear that it will rise in the vertical column to the same level as in the tank. Now assume that a specific quantity of compressed air is allowed to continuously flow into the pipe. The mixture of air and water in the vertical pipe, because it is lighter than the water in the tank, would rise a distance of $H_1 + A$ above the water in the tank. This is true because the light mixture of air and water in the column $H_s + H_1 + A$ just balances the head of pure water "H_s" in the tank. With this condition, no water is flowing, since the system has reached a static position. Assume that, after the static position has been reached, a section of the pipe is cut off, say "A" amount. Now, the mixture of air and water in the column no longer balances the head of pure water in the tank and the result is a flow of water up the vertical column. The actuating force is equal to the unbalanced force of the column of mixture due to deducting "A." This actuating force is equal to the pressure exerted by the head of pure water H_s (submergence) less the pressure exerted by the head of the mixture H_1 (lift) + H_s (submergence).

Terms

H_g = Distance from ground level to point of discharge = Lift above ground in feet.

H_n = Distance from the water level to the ground level when the well has been allowed to stand for some time without pumping = Static lift in feet.

H_d = Distance from the water level when the well is pumping the desired quantity of water to the water level when the well is not pumping = Drawdown at required water capacity in feet.



H_1 = Distance from pumping level to point of discharge = $H_g + H_n + H_d$ = Total lift in feet.

H_m = Distance from entrance of air into discharge pipe to the static or normal water level = $H_d + H_s$ = Starting submergence in feet.

H_s = Distance from entrance of air into discharge pipe to the pumping water level = Working submergence in feet. This factor is often expressed as per cent submergence which is

$$\frac{100\,H_s}{H_s + H_1}$$

*Courtesy, Ingersoll-Rand Co.

Data Used in Air Lift Calculations

Quantity of Air Required

$$V_a = \frac{H_1}{C \log_{10} \frac{H_s + 34}{34}}$$

in which

V_a = cubic feet of free air per gallon of liquid.
H_1 = total lift in feet.
H_s = working submergence in feet.
C = factor varying with submergence; given below.

Submergence	Value of C — outside air line	Value of C — inside air line
75%	366	330
70%	358	322
65%	348	306
60%	335	285
55%	318	262
50%	296	238
45%	272	214
40%	246	185
35%	216	162

Submergences

Lift in Feet	Customary Allowable Submergence Percentage	Best Submergence Percentage
20 to 125	50 to 70	65-70
125 to 175	40 to 65	60-65
175 to 250	40 to 60	55-60
250 to 350	37 to 55	50-55
350 to 650	37 to 50	45-50
650 to 750	35 to 45	40-45

Size of Discharge Pipe

$$d = 13.54\sqrt{\frac{Q}{v}}$$

in which

d = inside diameter of pipe in *inches.*
Q = Volume of the mixture of air and water in cu. *ft.* per min.
v = velocity of mixture in pipe in *ft.* per min.

With a straight pipe the best discharge velocity of the mixture of air and water for lifts from 40 to 200 ft. varies from 2000 ft. per min. at 35% submergence to 700 ft. per min. at 70% submergence.

With a tapered pipe the best discharge velocity is 1400 ft. per min. at 35% submergence and 550 ft. per min. at 70% submergence. The best velocity for the mixture of water and air at the entrance to the bottom of the discharge pipe is 800 ft. per min. at 35% submergence and 450 ft. per min. at 70% submergence.

Starting Pressure

$P_s = 0.434\ H_m$

in which

P_s = starting pressure in lbs. per sq. in.
H_m = starting submergence in feet.

Working Pressure

$P_w = 0.434\ H_s + P_f$

in which

P_w = working pressure in lbs. per sq. in.
H_s = working submergence in feet.
P_f = friction drop in air line from the compressor to the foot piece in lbs. per sq. in.

For "Sewage and Sludge Pumping" (See Sewerage Section)

RATING AND SAMPLING WELLS BY AN IMPROVED METHOD

By PAUL F. HOWARD, M.S.*

Boston, Mass.

It is oft-times desired and of importance to ascertain the quantity and quality of water yielded by an individual driven well connected to other wells of a water system. Experience has shown that analyses of samples of water taken from individual wells by means of a hand pitcher-pump give false and meaningless results, especially in relation to the iron content. Likewise the yield of an individual well by means of separate pumping furnishes but little if any information as to the yield of the individual well when ganged together into a common system.

The writer's firm was engaged to investigate a water supply from about 90 driven wells. During the course of the work it became desirable to determine the yield of each individual well and the iron content of the water from each individual well under normal operating conditions. This was done by a device which we have called a Well Rater and Sampler. The device (see cut) was connected to the top of the well by a 2½ inch wrought iron pipe about 2½ feet long. At this point a 1¼ inch centrifugal pump was connected by the proper fittings and discharged through a 2 inch pipe. On the suction pipe a hand pump was attached to prime the pump. A 2 inch orifice flow meter was inserted in the discharge line and by means of a manometer the rate of flow was determined. The amount of the draw-down of the well, when connected to the well field, was determined by means of a mercury U tube connected to a small tube attached to the well cap, the tube extending into the well to a depth sufficiently great so that the end was at all times below the level of the water-table outside of the well.

Before the Well Rater and Sampler was connected to the well the permanently installed valve on the suction line was closed. After the device was connected this valve was opened and the well was observed under actual working conditions—i.e., while it was being pumped along with the other wells by the large pump in the pumping station. The drawdown was revealed by the reading of the manometer connected to the tube in the well and recorded. Thereafter, the permanently installed valve was closed and the centrifugal pump started, the rate of pumping being controlled by a valve on the discharge line. As the discharge increased the drawdown increased, thus producing a deflection on the manometer. When the manometer reading was the same as that already observed under the actual working conditions, as just described, the output of the well was assumed to be the same. The quantity being pumped was then determined by observing the deflection of the flow manometer on the pump discharge line. The results represented the actual amount of water that the well was contributing from the field as a whole when under *actual* pumping conditions. Samples of water for analyses, then taken at the point of discharge, were considered truly representative samples.

By careful operation of the valve at the discharge end of the pipe the yield of the well was brought gradually up to the original yield at the beginning of pumping. Thereby higher velocities than usual or ordinary in the pipe well were provided. Any excess velocities would, of course, free scale, rust and other matter and give false samples. The flow manometer in this particular instance was connected to the 2 inch orifice flow meter. [The liquid used to determine the differential pressure can be of any specific gravity desired depending upon the rate of flow to be measured. The most common is mercury for high flows and carbon tetrachloride, Specific Gravity 1.60, for low flows.]

One side of the mercury U tube was connected to the tube in the well and filled with water from the surface of the mercury to the water level in the well, care being taken to remove all air. The other side of the U tube was left open to the atmosphere.

A Specific Case

The following specific example will serve as an illustration. After the Well Rater and Sampler had been properly set up and connected to a well the mercury U tube was connected to the tube in the well. There was an initial deflection of mercury of 3 inches which represented a water column of 40½ inches, the distance from the water table to the mercury surface of the U tube. After an equilibrium had been reached the well was connected to the field and the mercury in the U tube deflected an additional amount corresponding in general to the distance the water table dropped outside of the well and specifically to the drop in pressure in the well. In this case the total deflection was 4¼ inches or a difference in deflection of 1¼ inches which equal 17 inches of water as the drawn down within the well.

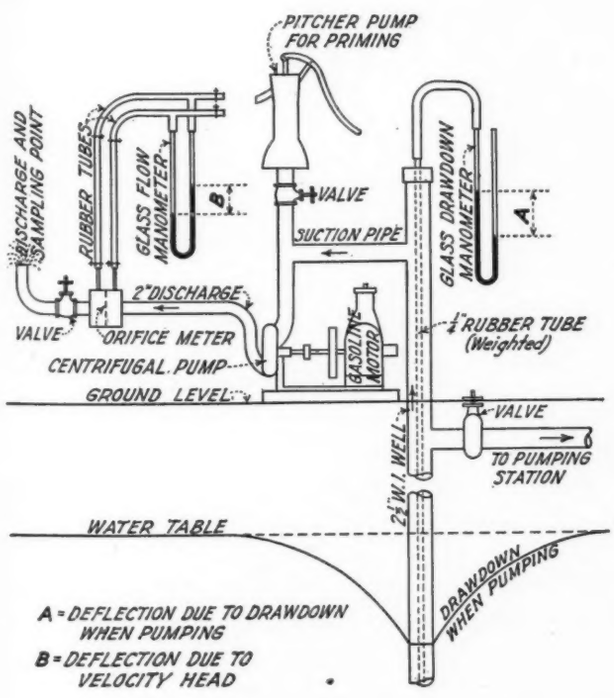
The well was then shut off from the other wells and the small test pump started. The discharge valve on the pump was then opened slowly, increasing the yield of the well until the drawdown deflection of mercury showed 4¼ inches. After this point was reached the flow manometer was observed to have a deflection of 1⅝ inches of mercury which on this meter represented a flow of 20.1 gallons per minute.

The yield of the various wells in relation to the drawdown was plotted on arithmetic paper and the yield of each well was found to be directly proportional to its drawdown. The yield of the various wells varied from 1 to 25 gallons per minute and the drawdown varied from 5½ to 26 inches.

This device has been made use of in installing new driven well fields. By its use we have been able to predict reasonably well the draw down or vacuum to be expected in a system of driven wells and to eliminate uneconomic wells, which have a low yield in relation to the drawdown. Also with open end wells it has been possible to determine at what yield a well will throw sand sufficiently to result in filling up by sand. The equipment will probably be found to have other uses also.

Acknowledgment—The above paper was presented before the New England Water Works Association, at Providence, R. I., Sept. 19, 1935, and appeared in WATERWORKS & SEWAGE for December, 1935.

*Whitman and Howard, Engs., Boston, Mass.



WELL RATER AND SAMPLER

The Hook-Up of the Well Rater and Sampler

M. B. SKINNER COMPANY

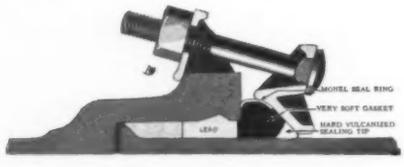
Repair Clamps and Saddles for Steel and Cast Iron Pipe

SOUTH BEND, INDIANA

SKINNER BELL JOINT CLAMP

●

For Stopping Bell and Spigot Joint Leaks . . .



CROSS SECTION

Cross section of Skinner Bell Joint Clamp shows at a glance the exclusive Skinner method of sealing gaskets under pressure. Note that soft rubber gasket is FULLY SEALED . . . at the bell face by Monel metal band . . . at spigot by hard vulcanized tips —sealing in pressure, sealing out air, moisture, and gasket-destroying soil conditions.

● SKINNER BELL JOINT CLAMPS give instant, effective and lasting repair for bell and spigot joint leaks. Direct in action, they not only stop the leak but also introduce an element of flexibility into the joint, which prevents future trouble at that point. This feature is especially valuable in repairing leaks that occur under railroad or street car crossings, or at other locations where vibration is present.

Clamps are rugged malleable iron, shaped to insure a perfect circle, and heavily enamelled to resist rust. Monel metal seal ring and ¾" cadmium plated steel bolts. Clamp is self-adjusting to variations in pipe thickness. For pipe sizes 3" to 48." Remember, Skinner clamps are the only clamps with SEALED gaskets; be sure to get this extra protection.

M. B. SKINNER COMPANY

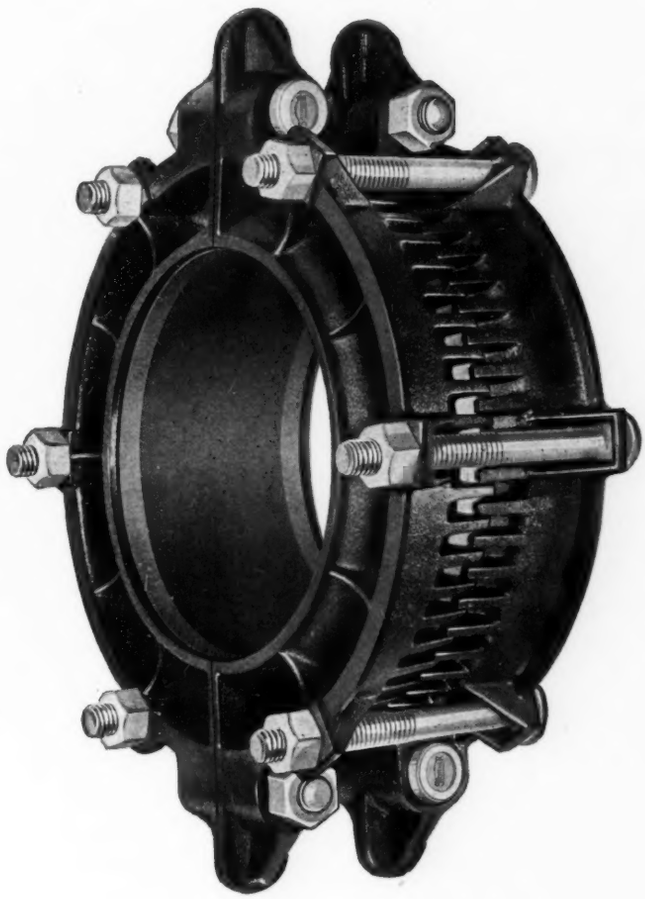
Repair Clamps and Saddles for Steel and Cast Iron Pipe

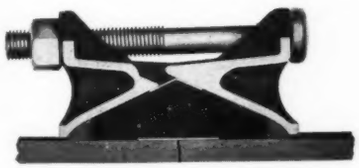
SOUTH BEND, INDIANA

SKINNER SPLIT COUPLING CLAMP

●

For Repairing Clean Breaks in Cast Iron Pipe . . .





CROSS SECTION

Cross section of Skinner Split Coupling Clamp shows how rubber gasket is COMPLETELY SEALED . . . at top by Monel metal sheath band . . . at the sides by hard vulcanized tips, sealing in the pressure, sealing out air, moisture, and gasket-destroying soil conditions. Note also brass band covering break.

● SKINNER SPLIT COUPLING CLAMPS are light and easy to handle . . . yet sturdy and dependable—strong enough to hold up to 600 lbs. pressure with ample excess strength guaranteed. One man can apply in only 12 to 20 minutes, with ordinary tools, and without shutdown of service. Saves expense and extra labor of installing clumsy sleeves; does away with wrapping and postponing the real repair. Introduces a degree of flexibility which prevents future trouble.

Construction is simple and effective. Two sturdy malleable iron rings—split for easy application—are tapered and cast with finger projections which intermesh. Molded gasket is 5¼" wide, of very soft gum and carbon black, with hard vulcanized tips. Monel metal sheath band, brass band to cover split, and cadmium plated steel bolts are furnished. For pipe sizes 2" to 16." WRITE FOR COMPLETE SKINNER CATALOG.

WELL CONSTRUCTION*

Some Notes and Experiences

By J. A. CARR

Superintendent, Water Department, Ridgewood, N. J.

In presenting this paper on well construction, let me say that I do not pretend to be an expert in this line. However, based on my own experiences, I shall attempt to bring to your attention a few points from the user's or purchaser's angle which may be of value to some.

My remarks will be confined to the drilling of wells in rock, that being the type of well with which I am most familiar.

The most important points in the construction of a new well seem to be the following:

1. Full and complete specifications and a bid sheet permitting a fair comparison of prices.
2. The selection of a responsible contractor.
3. A full-size hole, which is kept plumb.
4. Proper sealing.
5. Proper and complete testing.

Specifications and Bid Comparisons

It would seem as if the preparation of specifications for drilling a hole in the ground should be a simple matter. In my opinion it is not as simple as it first appears. There are several points both in the specifications and in the bid sheet which may cause difficulty in deciding on the low bidder and create misunderstanding in making payments. These points should be clearly set forth in fairness to both the contractor and the purchaser.

We, in Ridgewood, do not contract for a flat sum to a fixed depth, but call for bids by the foot. For instance, our bid sheet reads as follows:

Item 1. For drilling, furnishing, setting and sealing, both a ..... inch and a ..... inch casing from the surface of the ground to rock, as specified for $..... per lineal foot.

Item 2. For drilling a ..... inch well from the bottom of the casing to a point 150 feet deep for $..... per lineal foot.

Item 3. For drilling, etc., ... from a point 150 feet deep to a point 250 feet deep for $..... per lineal foot.

Item 4. For drilling, etc., ... from a point 250 feet deep to a point 500 feet deep, etc.

Usually the most expensive portion of the well is that portion which is cased down to and into rock. The depth into rock to which the casing will be carried cannot always be decided in advance. So, in order that all bids may be considered on an equal basis, the following statement is made in the specifications: "For the purpose of comparing bids, the distance from ground surface to rock will be considered to be ..... feet." The distance mentioned is the approximate depth we believe the rock to be.

Our specifications provide that we may stop drilling at any depth. Again, so that bids may be comparable, we state in our specifications: "While the contractor's bid is based upon a maximum depth of 500 feet, it is here distinctly understood that drilling may be stopped by the Engineer at any depth. It is guaranteed, however, that the contractor shall be paid for at least 200 feet of drilled well."

We provide that the well shall be tested once by, and at the expense of, the contractor. Furthermore, that more than one test may be required. In this precautionary specification, any uncertainty in bidding as to additional tests will be removed. The specified amount to be paid to the contractor for such additional tests is set up on an hourly basis.

Selection of Contractor

Next after the receipt of bids is the selection of a "skilled and experienced" contractor. This definition is taken to cover those who are not only responsible financially but, more important, those who know how and have the equipment to do a first class job. And, in addition, the desire to do it.

The improper care and use of drilling tools and improper handling of casings may result in defective wells, thereby causing much immediate or future trouble and expense.

There should be absolute insistence that the contractor's representative on the job, who is usually the rig operator, keep proper records and turn over to the purchaser full and complete information as to what is being done, and what is happening as the work progresses. Samples of drillings at various depths should be preserved.

Unfortunately, there are still some drillers who wish their operations to be considered secret. They should be impressed with the fact that there are two parties, the owner and the contractor, who should know all there is to know about the hole. Full and accurate records are most essential for the proper future maintenance and operation of the well.

What Size Hole?

The hole should be started at that size sufficient to permit as many reductions in diameter as may prove necessary and still have ample diameter for pump installation and to permit future work or alterations.

We recently had occasion to insert a 10-inch casing in a well that had already been reduced from 16 inches to 12 inches. Had the hole been started smaller, it might have been necessary to abandon it. It is poor economy to start drilling with a small hole.

The well should be plumbed and gauged at frequent intervals during drilling, in order that the purchaser may be assured a straight plumb hole of the required size. Watching the cable to see that it hangs in the center of hole is a rough check for plumb. The bits should be frequently checked to see that they are the full diameter required.

While a hole slightly out of plumb, so long as it is a straight hole, does not interfere to any great extent with a pump setting, a zigsag or corkscrew hole can cause no end of trouble and expense. This fact was vividly demonstrated to us recently when we inserted a 10-inch inner casing in an old 12-inch well. The casing above rock was out of plumb and there was a constriction in diameter of the rock hole which it became necessary to correct before the 10-inch casing could be entered.

Sealing

I believe that there is only one sure and permanent way of sealing a rock hole to shut off surface or top ground water. That is by double casing, in which the annular space between the two is grouted with neat cement.

On new holes we require the outer casing to be driven to the rock. The drilling is then continued the same size as the outer casing to a depth beyond all soft or broken formation, which is equal to the length of the string of tools. The hole is then filled with sand to a point where the inner casing is to set.

The balance of the hole is then partially filled with neat cement. A cast iron plate is welded over the bottom end of the inner casing and it is lowered and pushed into the cement to the required depth. This gives the inner casing a piston action forcing the cement around the bottom of the casing, and up into annular space between the two casings. The balance of the space is filled with cement slurry to the top. After the mortar has set for several days the cast iron plate is knocked out, the sand bailed out of the hole, and drilling continued into rock.

The purpose of the sand is to permit the string of tools to hand out of the casing when drilling is resumed, and thus avoid jarring and cracking the cement.

When inserting an inner casing in old wells, the hole is bridged at the required depth and the same procedure followed.

In placing the cement in the well considerable care is necessary, because if the cement is put in dry it has a tendency to bridge before reaching the bottom and not entirely fill the annular space. We have found it most satisfactory to mix the cement with water to the consistency of heavy cream and pour it in. Whether or not the space is entirely filled can be roughly checked by computing the volume of slurry required.

If the cement is placed dry, a small pipe carrying air from a compressor should be lowered to the required depth and gradually withdrawn as the hole fills. By this means the bubbling air prevents bridging of the cement.

*From WATER WORKS AND SEWERAGE.

UNITED STATES PIPE AND FOUNDRY CO.

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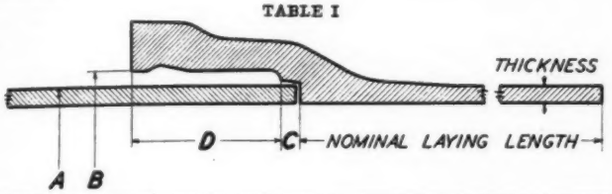
CHEMICAL CASTINGS
LARGE CASTINGS TO ORDER

Super-deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	150	.33	140	11.8		
3	250	.36	155	12.8		
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	30.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

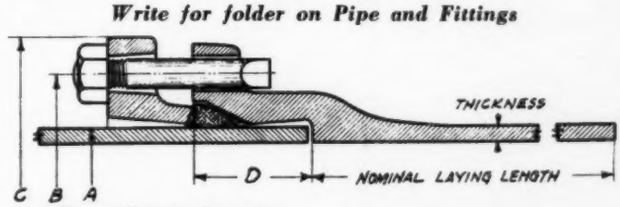
Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

THE U. S. JOINT

The U. S. Joint embodies the more favorable features of certain other types of mechanical joints and was developed and patented by the United States Pipe and Foundry Company after considerable study and research. It is adaptable to both Super deLavaud Centrifugal Pipe, and to pit cast pipe and fittings and these may be interchanged one with another in the laying of a line without the need of an adapter. The accessories, which consist of follower ring, gaskets and bolts are all interchangeable.

It possesses the following salient advantages:

Write for folder on Pipe and Fittings



1. **Ruggedness of parts.**
2. **High resistance to corrosion since all of the joint accessories are of the same material—cast iron.**
3. **Maximum joint deflection without leakage.**
4. **Great resistance to the flow of electric currents.**
5. **Ease of assembly—needs only one wrench.**
6. **Only one gasket per joint.**
7. **Excellent qualities as an expansion joint.**
8. **Tightness under high pressures of gas or water.**
9. **Connection to plain end existing pipe line without use of adater.**

ELIMINATING SURGE TROUBLES ON PUMP DISCHARGE LINES*

By D. M. RADCLIFFE

Engineer, U. S. Engineers' Office, Washington, D. C.

The purpose of this article is to relate a practical means of preventing dangerous surges and water-hammer in water service pipe lines.

There are several means of preventing surges in pipe lines, the best known of which is the surge tank. In most water supply systems it is not practical to provide surge tanks and therefore some other means must be employed if excessive surging is to be eliminated.

A common cause of dangerous water-hammer or surge in pipe lines of water supply systems is failure of the electric power input to motor driven pumping units. This sudden stop in pumping sets up a series of pressure waves or surges in the discharge pipe line. Much has been published with respect to water-hammer and its effects on pipe lines, therefore this article will discuss briefly a practical means of eliminating surge or water-hammer conditions. The method described is in satisfactory operation on the Washington Aqueduct in the city of Washington, D. C.

The Dalecarlia Pumping Station is equipped with nine synchronous motor driven centrifugal pumping units of 10 and 20 m.g.d. capacities. Three discharge pipe lines extend from the station to service reservoirs. One is a 48-inch pipe line, 12,350 feet in length with 110 feet working head; one a 36-inch line, 8,900 feet in length with 220 feet working head; one a 36-inch line, 15,950 feet in length with 340 feet working head. Three pumps are connected into each of these three lines.

Following accepted practice quick closing check valves had been installed in each of the pump discharge lines. Electric power failures, which occur several times each year, proved the cause of excessive and dangerous surges of water-hammer in the discharge lines. Records of the surges were taken on high-speed pressure charts and it was found that the maximum surge pressures recorded were 175 per cent above normal working pressure on each line.

Rotary Plug Type Check Valves Installed

After the pumping station had been in opertion for approximately three years, it was decided to install check valves which would reduce to a minimum the loss of head through such valves. The new valves installed are of the rotary plug type and hydraulically operated. These are equipped with an adjustable timing feature to provide means of regulating the speed of closing upon pump shut-down or failure of electric power. Timing tests were made on the new valves to determine, if possible, a closing period which would limit pipe line surges to safe values. A number of closing periods, varying from one second to fifteen seconds, were tried. It was not permissible to employ closing periods in excess of fifteen seconds because a reverse flow of water through the pumps would take place and rotate the units backward at high speed. Since the pumps are not designed for reverse rotation this condition was considered unsafe and time of valve closing was limited to a maximum of fifteen seconds. In the series of closing period tests made, it was found that a five second period produced the best results, but the surge was still 100 per cent above normal working pressure. Unless the check valve can be left open until a surge is dissipated and then closed slowly, it is necessary to close the valve before the first supernormal return wave reaches the station or valve. In the case of the Dalecarlia Station, the first

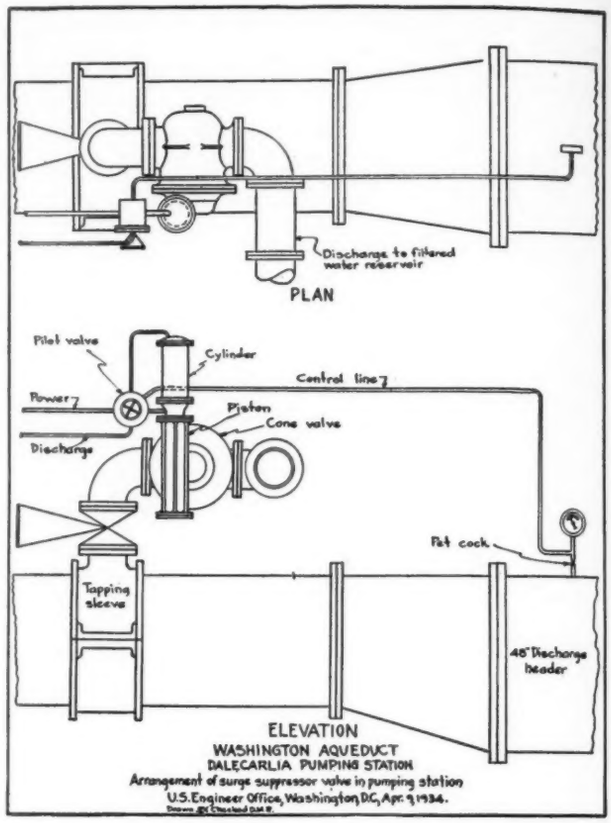


Fig. 2.—Sketch to Show Arrangement of Tapping Sleeve and Surge Relief Valves

*From WATER WORKS AND SEWERAGE, May, 1934.

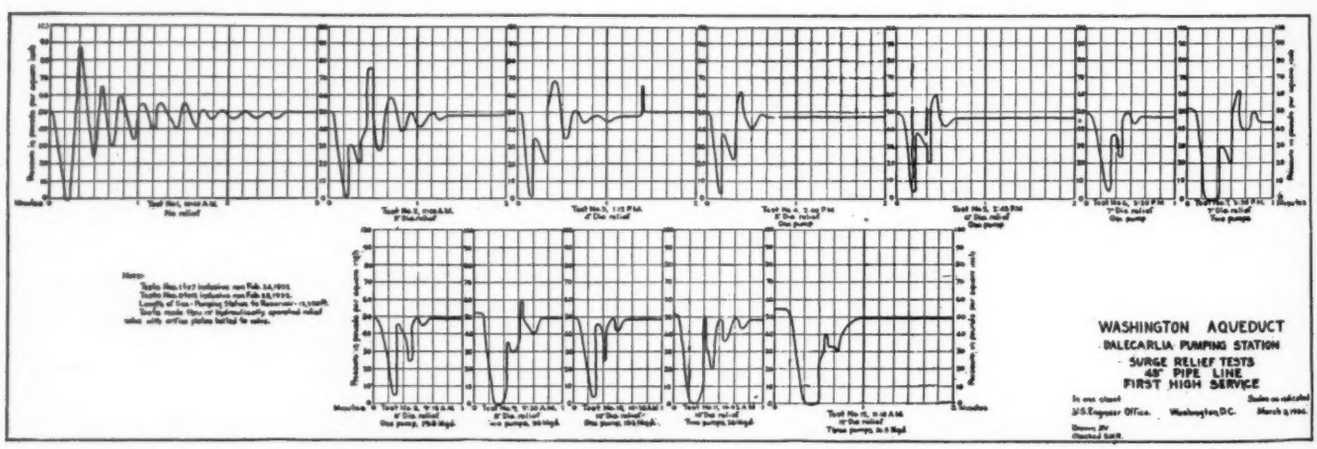


Fig. 1.—Results from Surge Relief Experiments, Employing Various Sizes of Relief Orifice

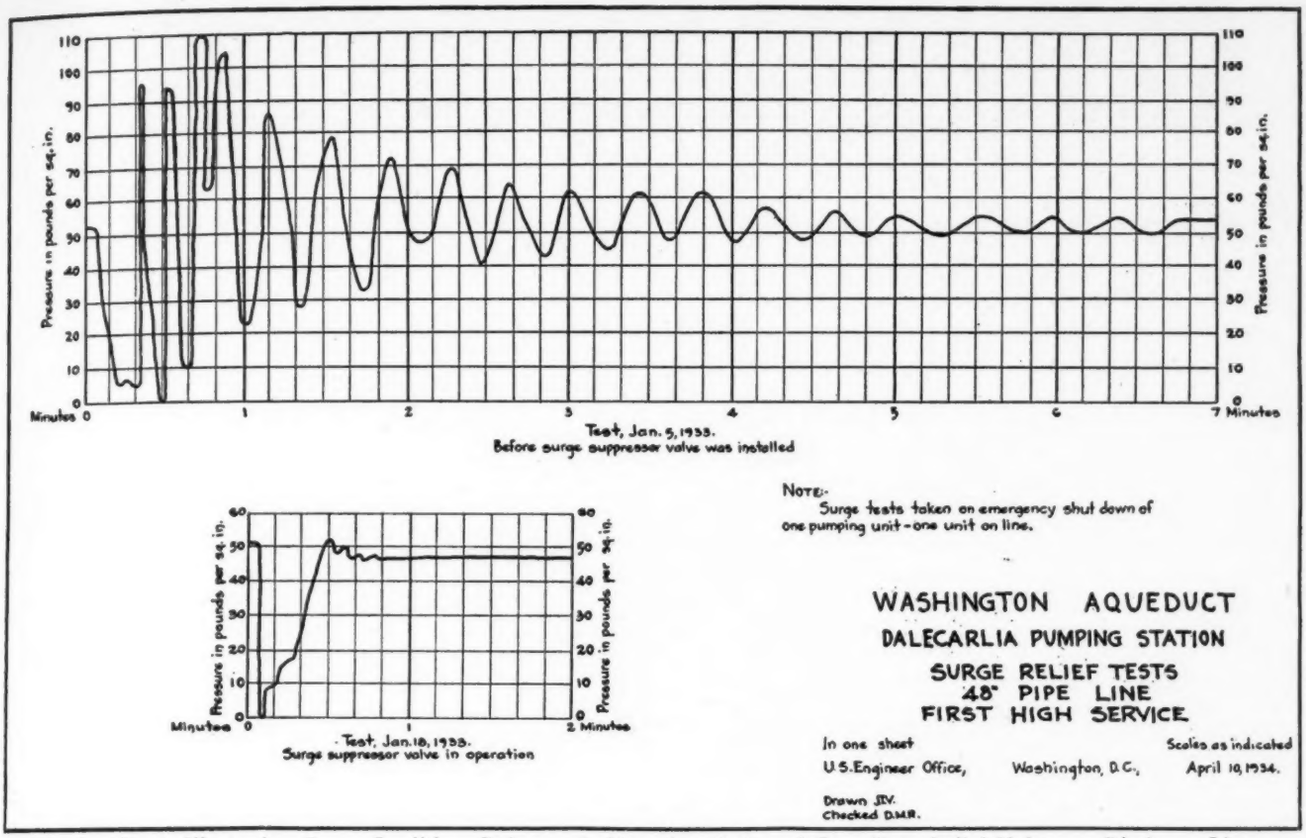


Fig. 3.—Charts Illustrating Surge Conditions Before and After Installation of Cone Type Relief Valves on Discharge Lines

supernormal wave reached the station seven seconds after power failure. The results obtained by valve timing were therefore not considered satisfactory because these valves must protect pipe lines of concrete construction which were not designed to withstand the surge pressures encountered.

Further Studies on Surge Relief

Investigations of several methods of surge suppression in pipe lines were then made. It was decided to provide a relief valve on each pipe header in the pumping station. To make the installation it was necessary to provide an outlet from each of the three pump-discharge lines. This was accomplished by installing "Smith" tapping sleeves (Fig. 2) with 10 inch outlets. A 10-inch gate valve was bolted to each sleeve to provide emergency shut-off. The discharge from each surge relief valve was carried into the filtered water reservoir to prevent waste of purified water.

Before deciding upon size of valves to be used, calculations and field tests were made to arrive at the size of relief required. The field tests consisted of a series of surge tests relieved through different sizes of openings. This was done by providing a 12 inch valved opening on one of the pumping station headers. A series of tests was then made under variable pumping conditions with the several orifice plates bolted on the valve. The valve was of the quick opening, hydraulic type, manually controlled. A signal system was installed to insure proper timing of test valve opening. The field tests included surge relief through openings 2, 4, 6, 8, 10 and 12 inches in diameter. It was found that the 2 and 4-inch openings had very little effect in damping the supernormal surge pressure. The 6-inch opening did not damp the first supernormal wave but did damp out the succeeding waves. The 8-inch opening entirely damped or eliminated all supernormal waves. From the results obtained in the field tests it was decided to install 10-inch surge relief valves on each of the pump discharge lines. The chart (Fig. 1) shows the results of the tests made with the orifice plates under variable pumping conditions.

Automatic Cone Relief Valves Installed

The surge suppressor or relief valves installed are of the hydraulically operated, rotary plug type (Fig. 2), manufactured by the Automatic Cone Valve Company, now a division of the Chapman Valve Company. Since the valves meet open when the pressure drops in the pipe lines it was necessary to supply water pressure for valve operating from an independent source of supply. A 60-gallon residential supply water system was installed to insure an unfailing supply of water pressure to the three surge relief valves. The valves operate in the following manner: the normal pressure of the pipe line operates against a spring diaphragm pilot valve which admits control water pressure to the "closing" end of the hydraulic piston.

This holds the surge relief valve in the closed position. When a power failure occurs, the water in the pipe line flows away from the pumping station causing a subnormal wave in the line. This results in low pressure against the control diaphragm, which allows a spring to operate the pilot valve, which in turn allows high pressure control water to flow to the "opening" end of the hydraulic piston which opens the main surge relief valve. The opening action is very rapid, the entire operation requiring only from 1.5 to 2 seconds. The average duration of the first sub-normal wave in the Washington lines is approximately 8 seconds, thus the surge relief valve is wide open before the first super-normal return wave reaches the station. With the surge relief valve open, all succeeding supernormal waves are dissipated through the open valve. The pipe line now assumes a penstock condition and the surge relief valve must be closed very slowly in order to prevent setting up penstock surges. This is done by limiting the flow of control water to the "closing" end of the hydraulic piston. For successful results it was found that a 2-second opening and 2.5-minute closing of the surge relief valves entirely eliminated water-hammer or surges in the respective pipe lines.

Results

During the period of service since these surge relief valves have been in operation in the Dalecarlia Pumping Station several power failures have occurred. High speed pressure charts indicate, however, that pipe line surges have been entirely eliminated as indicated by typical records pictured in Fig. 3.

R.D.WOOD CO.

ESTABLISHED IN 1803

400 CHESTNUT STREET
PHILADELPHIA

WORKS, FLORENCE, N. J.

SAND-SPUN PIPE

Centrifugally Cast in Sand Molds for High Strength

"Sand-Spun" pipe is fundamentally different from pit-cast pipe in its manufacture and in its properties. It is cast in heated, spinning sand-lined molds. This process eliminates chilled iron, hardness, and brittleness, and produces a pipe with few impurities, great elasticity, and high tensile strength. The metal is close grained and ductile, making drilling and machining easy.

"Sand-Spun" pipe conforms to American Water Works Association and American Gas Association standards for Bells and Beads. It is available in unlimited quantities in sizes up to 30″, in bell and spigot, plain ends, raised ends, grooved ends, and with mechanical joints.

FITTINGS

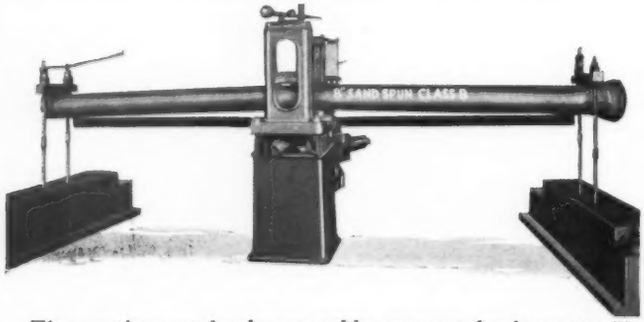
Bell and Spigot or flanged fittings made to American Water Works Association specifications.

Special castings, flexible-joint pipe, and large loam castings.

Cast iron culvert pipe.

Highly Recommended for

WATER, GAS, LIQUIDS, SEWERS



The continuous shocks caused by present-day heavy traffic on hard surfaced streets require a pipe more resistant to shock. Thus we show here an illustration of the elasticity or bending quality of SAND-SPUN pipe. This 16-foot section bent more than 3 inches without damage.

Reduced Fittings: Condensed design of bells and spigots, interchangeable with A. W. W. A. standard, A. G. A. standard, and N. E. W. W. A. standard. They effect savings in weight, space, freight, and handling.

GATE VALVES

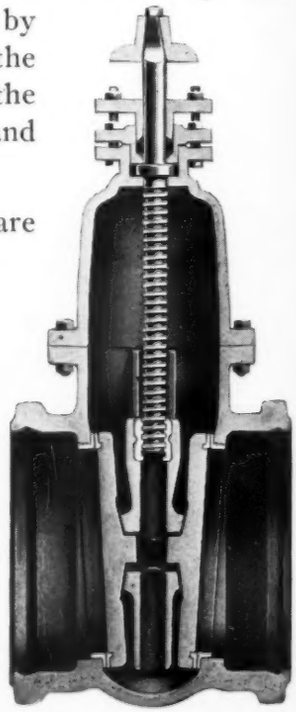
Every element in the design and construction of "Wood" Gate Valves is based on the fact that **reliability** is their all-important quality. Interruptions in service are fire hazards, or perils to health, or both.

"Wood" Valves, therefore, are primarily simple in design, rugged in construction, fully bronze mounted, and tested to twice their working pressures of 175 pounds. They fully meet specifications of American Water Works Association, with these two added features:

1. There are no pockets to fill with sediment or scale to make the valve jam.

2 The taper-tube seat, with double discs to assure tightness, is never rubbed or scraped by the discs, because the mechanism drops into place before it is spread by outward pressure from the center. This protects the seat against wear and grinding action.

Wood gate valves are available in every size.



In closing, the gates lower out of the bonnet across the flow of water before the spreading action begins. The center or "hub" of the spreader then presses outwards against the discs on each side of the trunnions, creating a uniform pressure and a perfect adjustment against the seats. In opening, the spreader moves away from the discs, letting them fall free before lifting.

MATHEWS FIRE HYDRANTS

The Mathews Hydrant has been a leader for more than 60 years. Over 350,000 are in use. They have never changed in basic design, and the newest Mathews is interchangeable with the oldest.

Yet the Mathews Modernized Hydrant is the one hydrant best fitted to meet today's requirements. Not only is it simple in design, thoroughly protected against rust, and unusually strong in all its parts, but the protection-case construction offers three distinct advantages:

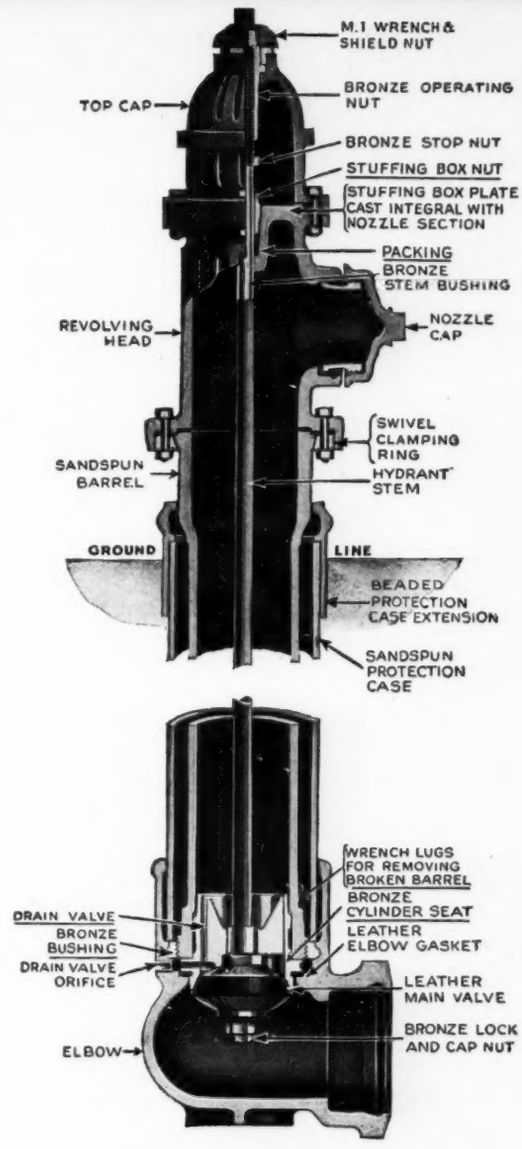
1. It prevents frost-swollen ground from heaving the hydrant, loosening it from the main, breaking it away from the main, or cracking the hydrant itself. It is only natural that tightly packed soil lifts under the action of frost, and may hoist the hydrant several inches out of position. But in the case of Mathews Hydrants, this upward pressure is exerted only on the sliding protection case. Frost cannot heave the hydrant itself, and leaves it without strain at the level it was set.

2. It makes the hydrant far stronger. Not only is the full barrel-strength increased by the shock-resistance of the sand-spun protection case, but the hydrant is not weakened by any theoretical breaking point.

3. The protection case allows all working parts to be unscrewed and lifted out as a unit, whether broken by traffic, in need of overhaul, or for replacement by the modernized type. It is never necessary to dig up a Mathews Hydrant, for even grade-changes can be met by replacing the barrel with one of the proper length.

The Modernized Mathews also has the advantage of the new Swivel Flange which permits facing the nozzles in any direction, and the Shield Operating Nut which prevents rain and sleet from seeping in and freezing around the operating nut.

And remember: Traffic-broken Mathews Hydrants can be replaced without digging or breaking pavement. This is a real economy to any municipality.



MATHEWS MODERNIZED HYDRANT

Products by R. D. Wood Co.

Mathews Fire Hydrants
Gate Valves
Air Valves
Foot Valves
Check Valves
Valve Boxes
Indicator Posts
Floor Stands
"Sand-Spun" Pipe
Pit Cast Pipe
Oval-Seal Mechanical-Joint Pipe
Standard Fittings
Reduced Fittings
Oval-Seal Fittings
Cutting-In Specials
Drips and Syphons
Large Loam Castings
Gray Iron Castings
Hydraulic Machinery
Hydraulic Operating Valves
Automatic Gas Producers
Blast Furnace Gas Washers

THE ELIMINATION OF CHECK VALVE SLAM

By H. K. PALMER*
Los Angeles, Cal.

The slamming of check valves when pumps are stopped constitute a source of annoyance and often of expense to water works or sewage works, and allied institutions. Many check valves have an annoying habit of slamming when it is least expected, while others placed on long lines may close quietly. Too sudden closing may easily cause a rupture in a pipe line, a feature which may be eliminated by inclusion of a large air chamber which will eliminate sudden pressure on the pipe but may cause such an abrupt closing of the valve as to crack the flap.

Check valve slam produced by a surge in the water column causes water hammer, with its consequent damage. When a pump suddenly stops, the water tends to continue in motion due to its momentum, and the gage pressure drops to zero. The force tending to stop the motion of the water is proportional to the static head on the pump and such force produces a negative acceleration in the water column according to the formula:

$$F = Ma$$

where: F = Force producing acceleration; M = Mass of water; a = Acceleration.

Letting: A = Area of pipe, square feet; L = Length of pipe in feet; g = Acceleration due to gravity (32.2); w = Weight of a cubic foot of water (62.4 lbs.); h = Static head on the pump; Hf = Friction head; H = Total head; t = Time in seconds; v = Velocity in pipe:

One may: compute the force producing acceleration as being

$$F = h\,A\,w$$

And, the mass of water is found to be

$$M = \frac{A\,L\,w}{g}$$

Then:

$$h\,A\,W = \frac{A\,L\,w}{g}\,a$$

Or

$$a = \frac{h}{L}\,g \qquad \text{(See Figue 1)}$$

If v is the velocity in the pipe before the pump stops, the time (in seconds) required to bring the water to a stop will be

$$t = \frac{v}{a}$$

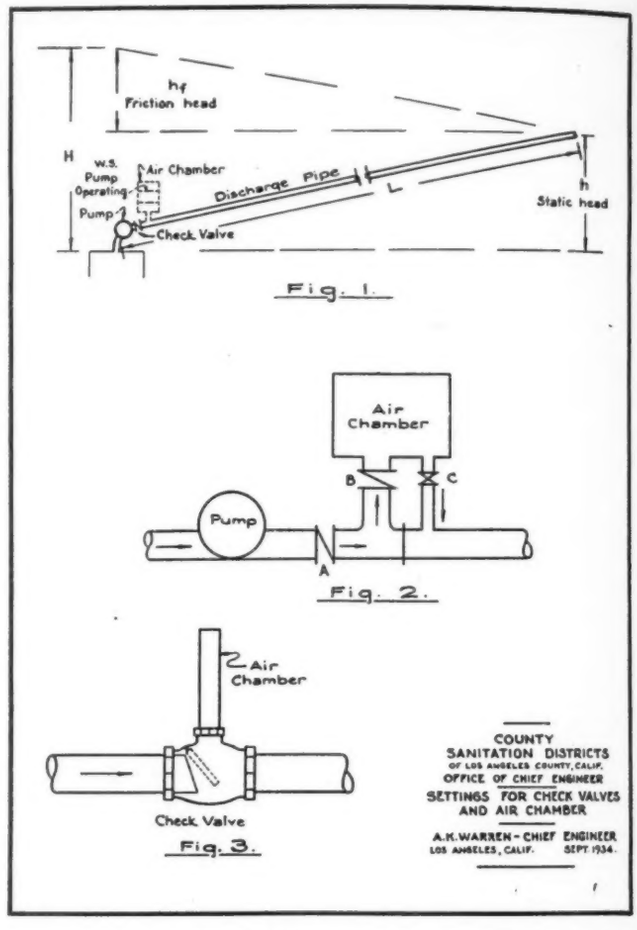
If the flap can come to its seat in (t) seconds or less, it is obvious that the water cannot move backwards and as the flap is moving against the stream it will be cushioned. On the other hand if the flap does not have time to become seated within (t) seconds, the water will start backwards and the valve will close with a slam.

Rapid vs. Slow Closing Checks

It is obvious that what is desired is *a valve that will close rapidly*. One way to accomplish this is to have the valve seat inclined to shorten the distance the flap must move, and another is to use a valve with an extended hinge pin and arm so that the flap can be weighted. This weight prevents the flap from opening fully, causing a small increase in pressure, but accelerates its return movement when the pump stops. On one test in which a four-inch pump was forcing water into a pneumatic tank under 65 pounds pressure, the slam was eliminated by hanging enough weight on the check hinge pin arm to increase the pumping pressure less than one-half pound. This represented one of the most difficult situations for slam elimination because the pump line was short and there was little mass to the flowing water; thus in one controlling formula $a = \frac{F}{M}$, (a) was relatively large; and in the other formula $t = \frac{v}{a}$, (t) was relatively small.

Where it is not practicable to close the check valve in less than time (t), the use of *a slow closing valve* should be considered, but such valves are expensive and must be so designed that the final closure is made very slowly. An air chamber will provide a cushion in case the valve does not close before the flowing water comes to rest and will protect the pipe against excessive pressure. Immediately after the pump stops, the value of the shock absorbing compressed air in such chamber is its cushioning effect, which tends to maintain the gage pressure on the line instead of allowing it to drop to zero. It will thus delay the stopping of the water in the main pipe but the pressure being maintained close to the pump, where the air chamber will normally be placed, produces excessive acceleration in the short length of pipe between the chamber and pump and although the valve will slam violently, the pressure on this section of the pipe will not be excessive. After the valve has slammed the water in the main pipe will slowly come to rest, and then back into the air chamber, the gage showing an oscillation about the static elevation, as a center, with maximum and minimum at approximately $(h + H_f)$ and $(h - H_f)$.

The air cushion in Fig. 1 has purposely been drawn much larger than is recommended in order to illustrate the conditions. If, instead, it consists of a piece of pipe of the same diameter as the discharge pipe and about two or three diameters in height it will not supply enough water to permit any to flow backward through the check valve, thus avoiding a slam and at the same time preventing excessive pipe pressure. A surge will be set up with a maximum pressure of $(H = 2h)$ and minimum $(H = o)$.



Arrangements of Air Chamber Installation to Eliminate Check Valve Slam and Water Hammer

*Chief Draftsman, Los Angeles County Sanitation Districts.

A Successful Arrangement

An air chamber arrangement which has been found to work very successfully is shown in Fig. 2. "A" is the main line check valve, "B" a check valve into the air chamber which should be nearly as large as "A" and set to allow water to enter the chamber. "C" is a gate valve or a plug cock smaller than "B". "C" must be opened or closed by trial until it limits the flow of water from the air chamber enough to prevent slamming of valve "A," and thereafter left in that position. The limited supply to the pipe damps out the surge, yet check valve "B" is large enough to admit a full stream to the air chamber and thus prevent excess pressure on the return flow.

To correct slam in an existing check valve, an air chamber can be built into the cover plate of the valve (Fig. 3). Care must be taken to so adjust the size of such a chamber that sufficient water is returned to close the flap by the time the water comes to rest but not sufficient to produce a slam.

This investigation was made about five years ago by the writer for the Los Angeles County Sanitation Districts and the data obtained applied to the correction of a number of troublesome conditions where valve slam was a problem.

The writer is indebted to E. A. Rutledge of the Rensselaer Valve Company for testing the formulae on many successful water works installations. A. K. Warren is Chief Engineer and General Manager of the Sanitation Districts and A. M. Rawn is Assistant Chief Engineer.

WATER SERVED AT WELL-WATER TEMPERATURE

By WM. M. RAPP

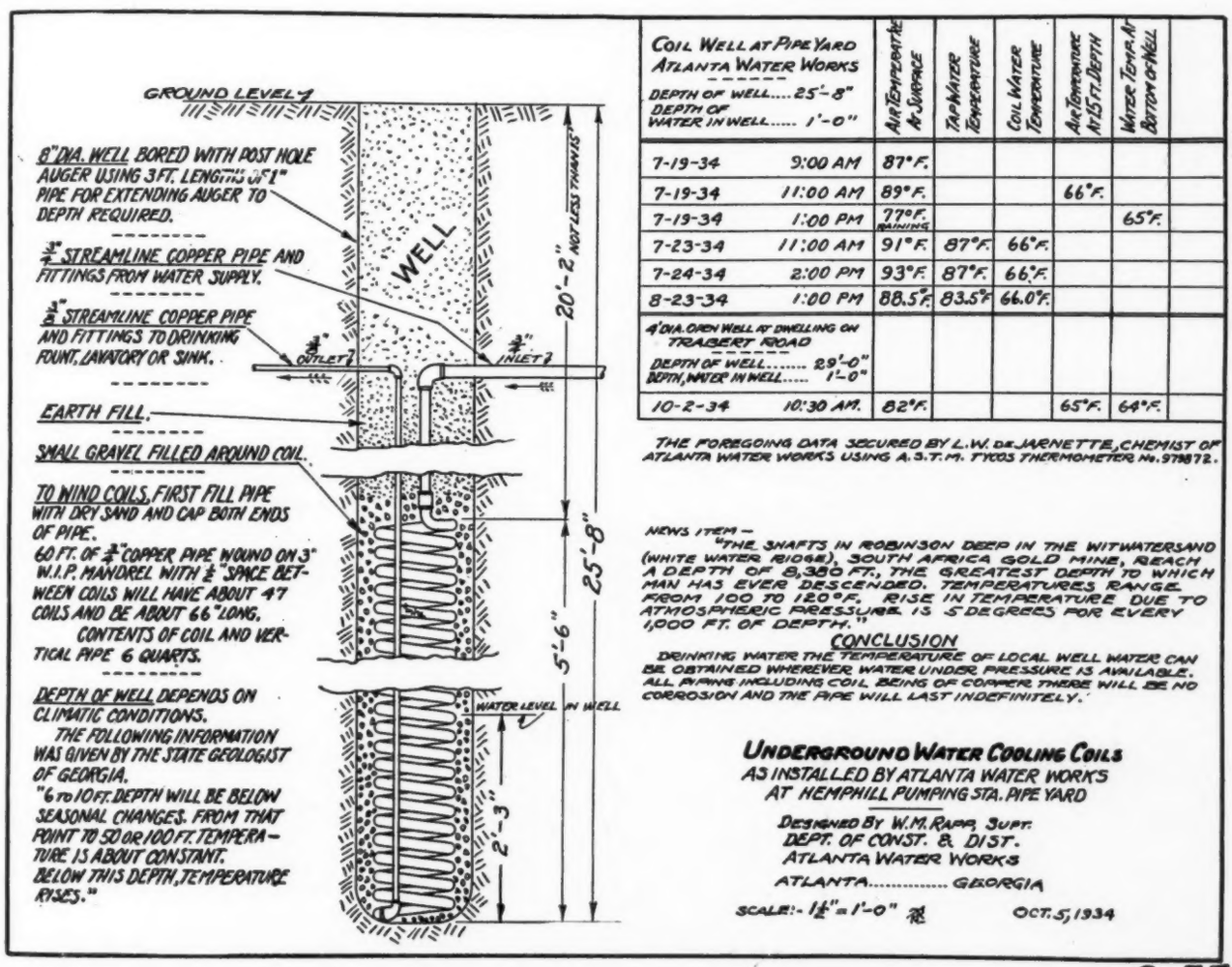
Superintendent of Distribution, Atlanta Water Department, Atlanta, Ga.

A cool drink of pure water on a hot day is very refreshing but few municipalities or private concerns are equipped nor can they afford to supply artificially cooled water to their drinking fountains in parks, on golf links and elsewhere.

The Atlanta Water Department has had two ground water-coolers, similar to the one shown in the accompanying illustration, in service for the past four years and these proved to be so satisfactory that a third has been installed. From the functioning of this last installation the data shown on the sketch was obtained.

When air temperature was 93 degrees F. the tap water temperature from the city mains was 87 degrees F., but the temperature of the water from the depth-cooler was 66 degrees F. A check up against water temperatures in wells in the vicinity showed that the warm tap water, after passing the copper coils of the earth cooler, was the same temperature as waters in the wells.

The accompanying sketch tells its own story of how the coolers are constructed and the results obtained.


GROUND LEVEL
8" DIA. WELL BORED WITH POST HOLE AUGER USING 3 FT. LENGTHS OF 1" PIPE FOR EXTENDING AUGER TO DEPTH REQUIRED.
¾" STREAMLINE COPPER PIPE AND FITTINGS FROM WATER SUPPLY.
¾" STREAMLINE COPPER PIPE AND FITTINGS TO DRINKING FOUNT, LAVATORY OR SINK.
EARTH FILL.
SMALL GRAVEL FILLED AROUND COIL.
TO WIND COILS, FIRST FILL PIPE WITH DRY SAND AND CAP BOTH ENDS OF PIPE.
60 FT. OF ¾" COPPER PIPE WOUND ON 3" W.I.P. MANDREL WITH ¾" SPACE BETWEEN COILS WILL HAVE ABOUT 47 COILS AND BE ABOUT 66" LONG.
CONTENTS OF COIL AND VERTICAL PIPE 6 QUARTS.
DEPTH OF WELL DEPENDS ON CLIMATIC CONDITIONS.
THE FOLLOWING INFORMATION WAS GIVEN BY THE STATE GEOLOGIST OF GEORGIA.
"6 TO 10 FT. DEPTH WILL BE BELOW SEASONAL CHANGES. FROM THAT POINT TO 50 OR 100 FT. TEMPERATURE IS ABOUT CONSTANT. BELOW THIS DEPTH, TEMPERATURE RISES."
WELL
OUTLET
INLET
20'-2" NOT LESS THAN 15'
25'-8"
5'-6"
2'-3"
WATER LEVEL IN WELL

COIL WELL AT PIPE YARD
ATLANTA WATER WORKS
DEPTH OF WELL..... 25'-8"
DEPTH OF WATER IN WELL..... 1'-0"

		Air Temperature at Surface	Tap Water Temperature	Coil Water Temperature	Air Temperature at 15 Ft. Depth	Water Temp. at Bottom of Well	
7-19-34	9:00 AM	87°F.					
7-19-34	11:00 AM	89°F.			66°F.		
7-19-34	1:00 PM	77°F. RAINING				65°F.	
7-23-34	11:00 AM	91°F.	87°F.	66°F.			
7-24-34	2:00 PM	93°F.	87°F.	66°F.			
8-23-34	1:00 PM	88.5°F.	83.5°F.	66.0°F.			
4' DIA. OPEN WELL AT DWELLING ON TRABERT ROAD DEPTH OF WELL..... 29'-0" DEPTH, WATER IN WELL..... 1'-0"							
10-2-34	10:30 AM.	82°F.			65°F.	64°F.	

THE FOREGOING DATA SECURED BY L. W. DE JARNETTE, CHEMIST OF ATLANTA WATER WORKS USING A.S.T.M. TYCOS THERMOMETER No. 979872.

NEWS ITEM —
"THE SHAFTS IN ROBINSON DEEP IN THE WITWATERSAND (WHITE WATER RIDGE), SOUTH AFRICA GOLD MINE, REACH A DEPTH OF 8,380 FT., THE GREATEST DEPTH TO WHICH MAN HAS EVER DESCENDED. TEMPERATURES RANGE FROM 100 TO 120°F. RISE IN TEMPERATURE DUE TO ATMOSPHERIC PRESSURE IS 5 DEGREES FOR EVERY 1,000 FT. OF DEPTH."

CONCLUSION
DRINKING WATER THE TEMPERATURE OF LOCAL WELL WATER CAN BE OBTAINED WHEREVER WATER UNDER PRESSURE IS AVAILABLE. ALL PIPING INCLUDING COIL BEING OF COPPER THERE WILL BE NO CORROSION AND THE PIPE WILL LAST INDEFINITELY.

UNDERGROUND WATER COOLING COILS
AS INSTALLED BY ATLANTA WATER WORKS
AT HEMPHILL PUMPING STA. PIPE YARD

DESIGNED BY W. M. RAPP, SUPT.
DEPT. OF CONST. & DIST.
ATLANTA WATER WORKS
ATLANTA..... GEORGIA

SCALE:- 1½" = 1'-0" OCT. 5, 1934

S-75

Underground Water Cooling Scheme of Atlanta Water Department

PRACTICAL HYDRAULICS*

By P. S. WILSON
Glen Ridge, N. J.

I. The Sharp Crest Weir

The so called Sharp Crest Weir is a very useful device for the measurement of water flowing in open channels or streams. A knowledge of the few simple rules governing the design and use of weirs will make it possible to measure the flow of water shed streams contributing to reservoirs, to estimate the overflow or leakage of dams and to make other measurements of use to the water works operator.

By a Weir is meant a bulkhead or dam over which the water flows, or more particularly, a notch in the top of such a structure through which the water flows. As shown in the illustration (Fig. 1), it usually consists of a rectangular notch and it is then known as a Rectangular Weir.

The Crest of a weir is the bottom of the notch, the level to which the water must rise before any can flow over. It is the edge or sill over which the water flows. A weir is a Sharp Crest Weir when the bottom edge of the notch, or the crest, is constructed so as to be as sharp as possible, flush with the upstream face of the dam, and with the opening beveled or enlarged on the downstream side so that the stream of water as it passes through the opening will only touch the crest along one sharp edge, as shown in Fig. 2. In the laboratory the crest is kept as sharp as a knife edge. In practice the edge of a metal plate or angle iron, as shown in the illustration, is usually satisfactory unless extreme accuracy is desired. The upstream face of the weir should be vertical, and of course the crest should be exactly horizontal.

The Head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. With any given weir there is a fixed relation between the head and the amount of water being discharged, thus by measuring the head the discharge may be determined from the formula or table which applies to that particular form of weir in use.

The relation between the head and the discharge of a weir is different with different forms of crest and different shapes of notches. Different formulas must be used with such different weirs. The reason for making a weir sharp crested is that by so doing a weir can be built which can be used for the measurement of water without the necessity for making special tests to determine what the formula is. The formula for rectangular sharp crest weirs is known, and it has been found easier to reproduce standard conditions by the use of the sharp crest design than with most other forms. Most weirs built for the measurement of water are therefore constructed as sharp crest weirs.

Weir Formulas

One of the most commonly used formulas for use with rectangular sharp crest weirs is known as the Francis formula, named for its originator, Mr. J. B. Francis, who performed extensive experiments on weirs at Lowell, Mass., in 1851. This formula is as follows:

$$Q = 3.33 \times L \times h \times \sqrt{h}$$

In this formula:—

Q = Discharge of the weir in cubic feet per second.
L = Length of the weir crest in feet.
h = Head on the weir in feet.
$\sqrt{h}$ = The square root of the head in feet. The square root of the head is the number which, multiplied by itself, equals the head.

($h \times \sqrt{h}$ is often expressed as $h^{3}/^{2}$, but it is more readily computed if considered in the form given above.)

Example: A sharp crest rectangular weir is 5.00 feet long and has a head of 0.42 feet (5 inches) on it.

(The square root of 0.42 is 0.65, because $0.65 \times 0.65 = 0.42$.)

$Q = 3.33 \times 5.00 \times 0.42 \times 0.65 = 4.55$ cu. ft. per second.

The Francis formula given above is most accurate for heads between about 0.30 feet and 2.00 feet. A small error in determining the head makes such a large error in the discharge at very low heads, that for most practical purposes this formula is sufficiently accurate at all heads up to about 2.00 feet, and it is fairly accurate for higher heads also. The great advantage of the Francis formula is the fact that it is much simpler to compute than most of the others. The principal other formulas are known as the Bazin formula, the Fteley and Stearns formula and the Rehbock formula. A complete treatise may be referred to for the details of these other formulas.

For convenience the results of the computations from a weir formula may be arranged in a table, as shown in Table I. The discharge read from the table may be multiplied by the length (in feet) of any sharp crest weir to obtain the discharge.

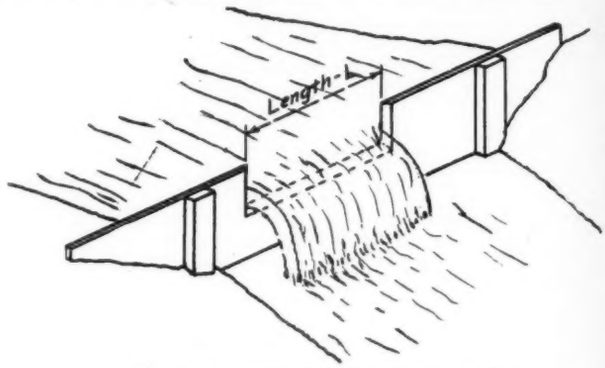


Fig. 1—Rectangular Sharp Crest Weir

TABLE I—DISCHARGE OF A SHARP CREST WEIR PER FOOT OF LENGTH BY THE FRANCIS FORMULA

Head Expressed in Feet	Head Expressed in Inches	Discharge per Foot of Length of Weir Expressed in Cubic Feet per Second	Discharge per Foot of Length of Weir Expressed in Gallons per Minute
.01	1/8	.0033	1.5
.02	1/4	.0094	4.2
.03	3/8	.0173	7.8
.04	1/2	.0266	11.9
.05	5/8	.0372	16.7
.06	3/4	.049	22.0
.07	7/8	.062	27.7
.08	1	.075	33.8
.09	1 1/8	.090	40.4
.10	1 1/4	.105	47.2
.12	1 1/2	.138	62.
.14	1 5/8	.175	78.
.16	1 7/8	.213	96.
.18	2 1/8	.254	114.
.20	2 3/8	.298	134.
.22	2 5/8	.344	155.
.24	2 7/8	.392	176.
.26	3 1/8	.441	198.
.28	3 3/8	.49	222.
.30	3 5/8	.55	246.
.32	3 7/8	.60	271.
.34	4 1/8	.66	296.
.36	4 3/8	.72	323.
.38	4 1/2	.78	350.
.40	4 3/4	.84	378.
.42	5	.91	407.
.44	5 1/4	.97	436.
.46	5 1/2	1.04	467.
.48	5 3/4	1.11	497.
.50	6	1.18	530.
.55	6 5/8	1.36	610.
.60	7 1/4	1.55	690.
.65	7 3/4	1.75	780.
.70	8 3/8	1.95	870.
.75	9	2.16	970.
.80	9 5/8	2.38	1070.
.85	10 1/4	2.61	1170.
.90	10 3/4	2.84	1270.
.95	11 3/8	3.08	1380.
1.00	12	3.33	1500.

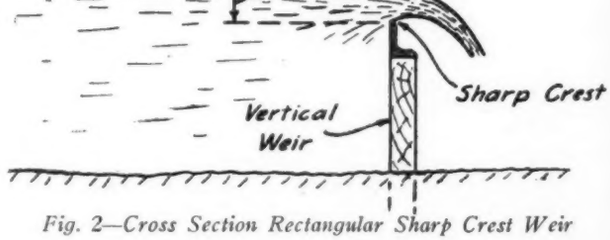


Fig. 2—Cross Section Rectangular Sharp Crest Weir

*From WATER WORKS AND SEWERAGE.
†Asst. Secy., American Water Works Assn.

II. The End Contractions of a Weir

There are two methods of constructing the ends of the weir. The first of these is shown in Fig. 3 and results in what is known as a weir *with end contractions.* In this design the sharp crest of the weir as formed by the bottom of the notch is continued up the ends of the notch, thus forming sharp edged ends for the weir. The water in flowing around these sharp corners then follows a course very similar to that taken in flowing over the edge of a sharp crest. In flowing around the edge from behind the weir it cannot change direction sharply and it curves inward toward the center of the weir contracting the stream as shown in the illustration.

The other method of designing the ends of the notch is to build it so that it extends the full width of the stream at that point, allowing the sides of the channel to form the ends of the notch and continue upstream at that width for a short distance, at least. An example of this method of construction is shown in Fig. 4. When so built it is known as a weir *without end contractions* because the water in this case flows straight over the crest, the stream continuing full width all the way. The weir thus consists of a simple dam or bulkhead across the channel.

It may readily be seen that if two rectangular sharp crest weirs have the same length and are flowing under the same head, the one that has end contractions (Fig. 3) is not discharging as much water as the weir without end contractions (Fig. 4). It has been found by experimentation that with sharp edged ends and a wide channel above the weir, so that the over-falling stream is fully contracted, the effect on the discharge of the weir is the same as if the length of the weir were reduced by a distance equal to one-tenth (0.1) of the head at each end of the weir.

For example: A sharp crested, rectangular, vertical weir is three feet long and the ends are so constructed that the flow will be fully contracted. If the head is one foot, then the effective length of the weir is reduced by one-tenth of a foot at each end making its effective length $(3.0 - 0.z) = 2.8$ feet—a reduction in capacity of about 7 per cent from the capacity it would have had without end contractions. Failure to make this correction might constitute a rather serious error.

If the head on the same 3 foot weir were only 0.1 foot instead of 1.0 foot (or if the length of the weir were increased to 30 feet with a head of 1.0 feet) then in either case the reduction in effective length would be only about 0.7 per cent which

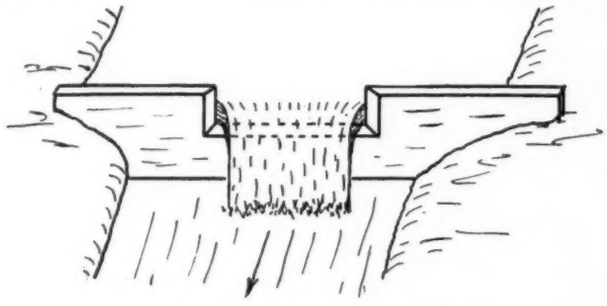


Fig. 3—Weir with End Contractions

would be a negligible error except in the most precise measurements.

It is thus seen that the importance of making the correction for end contractions depends upon the relative head and the length of the weir. If the head is more than one twentieth (5 per cent) of the length then end contractions will require a correction of more than 1 per cent and should certainly be accounted for.

Weirs are seldom operated in practice under a head sufficiently great in proportion to the length that the correction for end contractions is of importance. In such cases it is evident that it does not matter how the ends of the weir are built. Many weirs under practical conditions are built so that they do not have theoretically sharp edged ends and yet neither are they ended against the sides of the stream channel. The ends may merely be formed by the wood or masonry of which the dam bulkhead is built. In such cases we know that there is some end contraction but we do not know how much. Such a weir should be checked up to determine whether the end contraction correction would be of importance if it were complete. If it is found that the relation between the maximum head and the length of the weir is such that the correction would not be

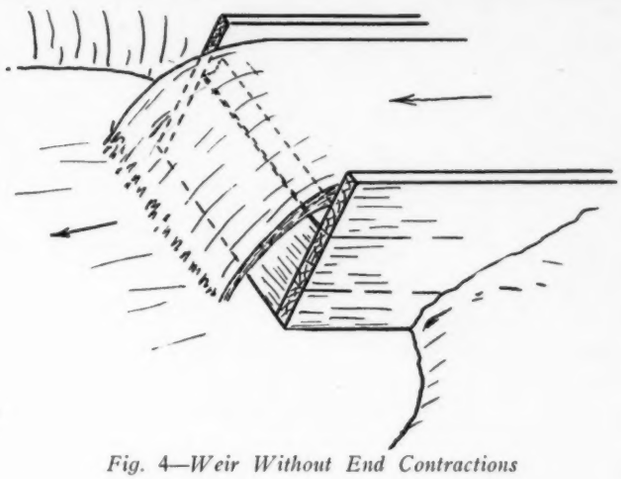


Fig. 4—Weir Without End Contractions

of importance (less than 1 per cent), then we know that it does not matter what it actually is and it can be neglected. It is found that the end contraction correction is of importance then either it must be estimated or else actual measurements of the flow must be made to determine what the correction actually should be. Usually it can be estimated. It is a help in estimating to actually observe the form of the stream during discharge of the weir.

If the relation between the length of the weir and the head is to be such that the end contraction correction will be of importance then the weir should, if possible, be built either with full contractions or with none at all so that the correction will be definitely known.

A weir may be built with a sharp edge on one end only so that the end has a full contraction and so that the other end has no contraction. The correction in such a case is, of course, only one-tenth of the head to be subtracted from the weir length.

III. Measurement of Head on Weirs

The measurement of flowing water by means of a weir depends in turn upon the measurement of the *head* of water on the weir. Having determined the weir formula to be used, depending upon the design of the weir crest, the presence or absence of end contractions and any other fixed condition, the recorded flow then depends upon the head. The head is the single remaining variable quantity. It is the quantity which is actually observed and measured in the field, the desired knowledge as to the amount of water flowing being then computed by the use of the formula, table or diagram. It is assumed in this discussion that the flow over the weir is not affected by backwater from below.

The head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. Figure 1 is a vertical cross section through a sharp crest weir with water flowing over it under a head indicated by (h). The shape of the upper and lower water surfaces shown in this figure have been determined by measurement and have been found to have forms similar to these, regardless of what the head is, so long as the weir has a sharp crest and a vertical upstream face. Under special conditions at low heads the water may, however, cling to the downstream face of the weir.

Figure 1 shows clearly the fact that in this general case the

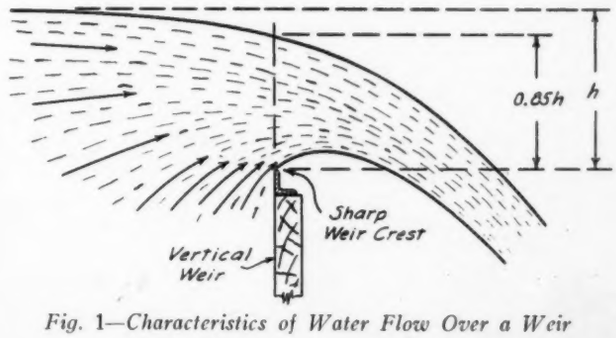


Fig. 1—Characteristics of Water Flow Over a Weir

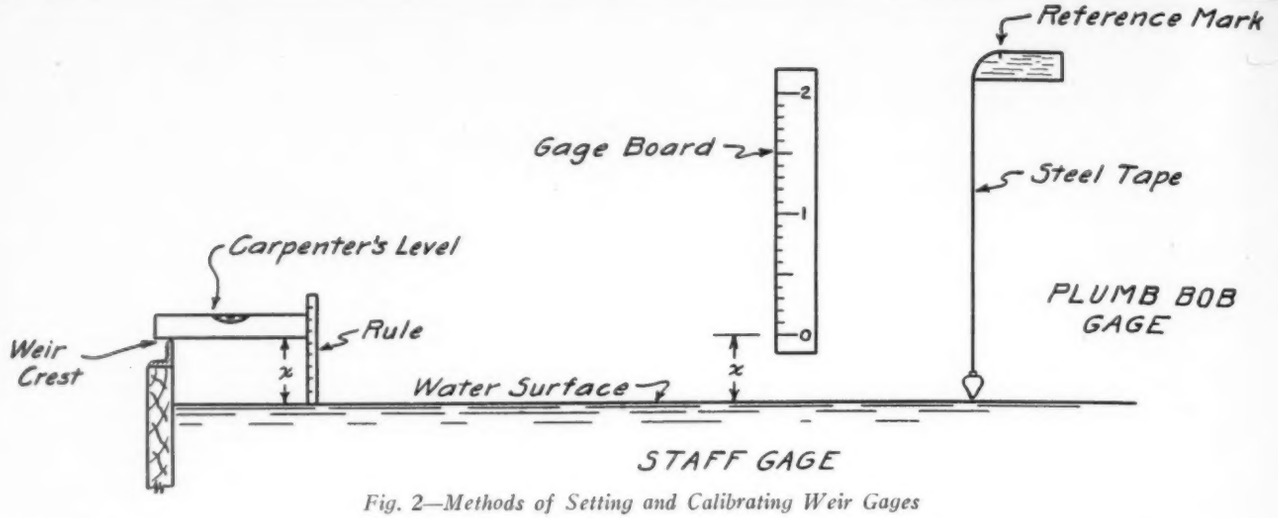


Fig. 2—Methods of Setting and Calibrating Weir Gages

water only touches the crest along the one sharp edge and then leaps free. The arrows showing the converging stream indicate the reason for the shape which the lower surface of the water is found to take. There is one very important fact to be noted from Figure 1—namely, the upper surface of the water starts to curve downward before it reaches the weir. This results in the depth of water at the weir crest actually being only about 85/100ths of "h" (expressed as 0.85h)—the condition which makes it necessary to measure the height of the water surface at some distance upstream from the weir when determining the head. The height of the water surface should be measured at a point located upstream from the weir *a distance at least equal to three times the maximum head* to be encountered.

Measuring Gages

The type and design of gage to be used to determine the water level depends upon the accuracy desired and the conditions under which it will operate.

The Staff-Gage

The simplest and most commonly used type of gage consists merely of a strip of wood or metal with the necessary graduations marked upon it. A section of a carpenter's rule or a surveyor's rod may be used if adequately waterproofed by varnishing. One of the best forms of gage board consists of a vitreous enameled ware metal plate mounted on a wood plank. The graduations and figures are baked into the enamel. Gages such as these, often called staff-gages, if well graduated and carefully read will enable the water level to be determined to within about 0.01 feet, equivalent to about ⅛ inch. This is sufficiently accurate for most purposes other than studies requiring laboratory refinements. One of the greatest disadvantages of this type of gage, however, is the necessity for locating the observer's eye near the water level when taking a reading. This is not always convenient. Care must be taken to read at the true water surface and not the height to which the water surface curves upwards where it wets the gage.

When mounting a staff-gage great care is needed to insure that the zero of the gage is exactly level with the crest of the weir and that it remains so. A small error in this respect will cause a large error in the results, particularly at low heads. Moreover, this error will always be in the same direction and will not tend to correct itself or be compensated for by other errors.

By the careful use of a surveyor's level a gage may be set with sufficient accuracy. If a surveyor's level is not available then the water surface itself may be used in the manner indicated in Figure 2. Choose a time when the water surface is not rising or falling too rapidly and preferably when it is lower than the weir crest. By means of a carpenter's hand level and rule measure the distance (x) down to the water surface from the weir crest. Then measure up from the water surface at the gage location and set the gage zero the same distance (x) above the water level as the weir crest was found to be. Then, afterward, such gages should be regularly checked to be certain that they have not been moved, and that the zero point is correct.

Plumb-Bob Gage

Another form of gage is known as a plumb-bob gage. It consists of a graduated steel tape with a heavy plumb bob on its end. It is used to measure from a fixed reference mark, above water level, down to the water surface. By allowing it to swing slightly the contact of the plumb bob with the water surface may be very accurately noted. This naturally assumes the water surface to be smooth. The plumb-bob gage may be most accurately read if the tape is run over a curved block of wood, mounted permanently above the water, which has the reference mark fixed on its upper surface, as indicated in Figure 2. The zero reading on this type of gage may be determined by measuring down to the water surface from the weir crest as shown in Figure 2 and applying the correction factor determined by a simultaneous reading of the tape.

Chain Gage

A similar type of gage known as a chain gage is often used. For the tape a chain running over a wheel is substituted. With this arrangement the position of a marker attached to the chain above the wheel is read along a horizontal scale. This type of gage is not so accurate as the former and it is not advised for weir readings except in the case of rough work or high heads. It is often used for river heights where accuracy within about 0.05 feet is generally satisfactory.

With all types of gages difficulty is introduced if the water level is disturbed by waves or surges. In the case of the gages above described this can only be overcome by the skill and patience of the operator in mentally averaging the indications while observing them over a short period. Practice can develop considerable skill in doing this.

IV. The Float Gage

Probably the most accurate type of gage, if well designed and constructed, is a float gage. Besides its accuracy it also has other advantages. Difficulty in reading due to waves and surges may be most readily overcome with the float type gage which is readily adapted to the use of an automatic recording mechanism. They may be classified into two types. The simplest type consists of the float with a rigid vertical stem attached to and supported by the float, with an index or pointer at its upper end. The gage reading is obtained from the position of this pointer along a fixed vertical scale. In the other type of float gage the motion of the float is transmitted to some form of indicating or recording mechanism by means of a flexible wire or tape.

The Float

A suitable float is the first essential. It must not become water logged, but must retain its buoyancy. To meet this condition a hollow sheet metal float is generally used, and copper is the preferred material because of its resistance to corrosion. The seams must be well locked and thoroughly soldered. Earthenware floats have been used in sewage or other corrosive liquids. Floats are most often made cylindrical with the axis vertical, in order to fit in a float pipe and, for ease of construction. It is important to have the top and bottom dished outward so that the float cannot be weighted with water on top or lifted by air trapped beneath. The float should have at least three vertical fins projecting a half inch or more from its sides in order to prevent it from clinging to the wall of the float pipe or well. Sometimes a spherical float is used, but in that case its weight, or its counterweight, should be adjusted so that it will float near its middle, in order to gain the maximum sensitivity.

Float Pipe

Floats are usually provided with some form of float pipe or stilling well. This serves two principal purposes—it serves as a guide for the float, and by adjusting the size of the communicating opening into the float pipe the effect of waves or surges upon the gage readings may be reduced. The use of a float pipe also makes it possible to locate the gage a short distance away from the body of water being observed, the level in the float pipe being maintained by a small size connecting pipe. With such an arrangement care must be exercised to avoid air traps in the connecting pipe. The connecting pipe should be made of non-corrosive material and should be provided with convenient means for flushing it out. A float pipe should be provided with a cover, having only a small opening for the wire or tape, in order to prevent objects from falling in and lodging on the float.

If the gage mechanism is light and easily operated, a 5-in. diameter float in a 6-in. float pipe makes a good combination. If a high degree of sensitivity is desired, or if a recorder requiring some power to operate it is used, then a larger float is desirable, a 10-in. float in a 12-in. pipe, or even larger, being often used.

Gage With Rigid Stem

The type of float gage having a rigid stem is the simplest and is also probably capable of the closest reading with accuracy, since the only friction involved in its motion is due to whatever guides may be needed to keep the stem upright and in the correct position with relation to the scale. The effect of this friction in preventing accurate response of the gage to changes in the water level may be largely if not entirely avoided by gently tapping the stem while reading the gage. Gages of this type, if properly designed and constructed, may be read directly to the nearest one thousandth of a foot (0.001 ft.), which is about the best in true accuracy that can be expected from single readings of any type of gage.

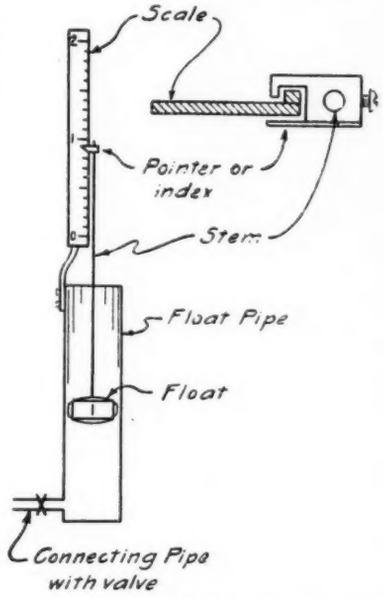


Fig. 1—Float Gage with Stem

An arrangement of this type of gage, which has been used extensively and which is highly suitable for accurate weir head readings, is shown in Fig. 1. In this design a 7-in. float may be used in an 8-in. float pipe. The float stem is a brass rod of about 3/16 in. or ¼ in. diameter, depending on the height. The best scale is made from a graduated brass strip about ⅛ in. thick. It is provided with a continuous projection along its back edge which serves to guide the index or pointer in the correct position for easy reading, and to hold the stem vertically above the float.

Gage With Flexible Wire

The second type of float gage, using a flexible wire or tape, is more adaptable to different arrangements, since the motion is usually converted into a rotary motion by the wheel or drum on which the wire is wound, and thus the readings may be shown on a circular dial, or a recording mechanism may be operated. It is not always so simple to overcome the friction of motion in this type of gage, and for that reason it may not be read quite so accurately unless the float is larger than with the rigid stem type.

A metal wire or tape is necessary for accurate readings in order to avoid changes in length due to stretching or moisture. The wire should be stranded, made from a large number of very small wires braided together, in order to be flexible and withstand frequent bending. Either wire or tape must be of bronze or other non-rusting metal.

The simplest arrangement of this type of gage consists merely of passing the wire over a wheel or pulley and having a counterweight on the end. Reading may then be taken from the motion of a pointer attached to the wire along a fixed vertical scale beside it. A very crude form of such a gage has often been seen on railroad water tanks.

A more usual arrangement in water works practice is to attach the end of the float wire to a drum, around which it is then wound a number of turns. The counterweight is then hung from another wire similarly attached to the drum. By such design slipping of the wire is avoided and the revolution of the drum is a true measure of the change in water level. The drum is then connected to a rotating pointer on a dial or to a recording device. By introducing suitable gearing a wide range of float motion may be shown as only a part of a revolution of the pointer on the dial, or other variations may be introduced changing the scale of readings to suit the conditions and the requirements.

The drum upon which the wire is wound should be provided with spiral grooves to receive the wire so that it will be guided in a single layer and will not wind upon itself, thereby changing the effective diameter of the drum and affecting the accuracy of the gage. If desired, the drum receiving the counterweight wire may be smaller than the drum for the float wire, thereby resulting in a shorter travel for the counterweight where this is of any advantage. The counterweight should not become submerged, since its effective weight would thereby be altered and the submersion of the float changed.

Gage With Tape

If a tape is used it is customary to provide it with uniformly spaced perforations which fall over similarly spaced projecting pins on the drum, thereby preventing slipping. A tape is, of course, not wound around the drum, but merely passes over it once, with the counterweight on the end. The counterweight must then travel through the same range of motion that the float does.

Indicators and Recorders

Many good designs of indicating and recording instruments are commercialy available for use with floats and which are adaptable to different conditions and requirements. Floats may also be utilized similarly to operate transmitters for long distance electrical transmission of gage readings, known as telemeters.

MAIN LINE METERING OF WATER AND SEWAGE

PART I—PRIMARY ELEMENTS

By L. D. CARLYON, M.E.
Cleveland, Ohio

In modern sewage plants and water works, metering equipment is now recognized for the important part it plays in obtaining efficient control and operation.

Regardless of type, large meters and registering devices depend upon the so-called "Venturi" principle for their operation. This consists of producing a differential pressure which varies in a definite and known relation to the rate of flow. The differential pressure is mechanically converted into terms of weight or volume and is so indicated and recorded by registering equipment. The actual registers themselves are constructed to provide various combinations of indicating, recording, and totalizing features.

There are three commonly used devices, which can be inserted in fluid lines to produce the desired differential pressure. These are the Venturi tube, the flow nozzle, and the thin plate orifice. Each provides a reduction of the area through which the flow takes place, thereby causing an increase in velocity at this point with a corresponding localized reduction in pressure. The result is a differential in pressure between two areas of the Venturi tube, or on either side of the flow nozzle or orifice inserted in the pipe. Figure 4 illustrates the head differentials created by an orifice insert.

For a given installation the primary element is designed and constructed so that when the maximum rate of flow occurs, a definite maximum head differential will be produced. This varies from a water differential of less than 10 inches to one of more than 200 inches, dependent upon the fluid to be measured, the static pressure, the maximum capacity and the type of register.

Although any one of the three primary elements (Venturi, flow nozzle, or plate orifice) can normally be used, there will usually be one of the three which is best suited to meet the existing requirements. The selection is determined by a number of factors. These factors are to be dealt with in this article, with a view of better acquainting engineers, superintendents or operators with the more important considerations in selection of metering devices. It is hoped that some of the confusion concerning these devices which exists in the minds of some will be cleared away by the following discussion.

Fundamental Comparisons

The Venturi Tube

The Venturi tube has been used for years in connection with projects of the hydraulic and sanitary engineer. As illustrated in Fig. 1, it is designed with a short cylindrical section at the inlet end of the tube, which is cast smooth inside. The high pressure connection is made at this point into the piezometer ring (Fig. 1, Section AA).

*Mechanical Engineer, Bailey Meter Co.

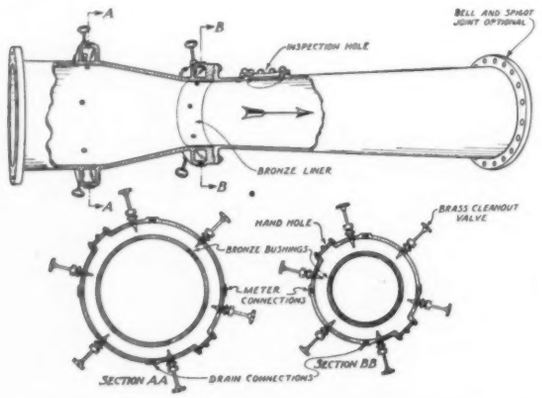


Fig. 1—Venturi Tube. (Handholes and Cleanout Valves Are Used Only for Measurement of Screened Sewage or Sewage Sludges)

Fig. 2—Venturi Throat Section for a 56-Inch Line, Constructed of Cast Iron with a Machined Bronze Liner

Following the inlet section is an entrance cone of about 21 degrees total angle, which leads to the short cylindrical throat section where the low pressure connection to the meter is made through another piezometer ring. At the throat the tube is flanged, and has a handhole which permits inspection of the throat and piezometer holes, as well as accurate measurement of the throat diameter. An exit cone, known as the diffuser, follows the throat and has a total angle of approximately 5 degrees. This ends in a flange for connecting the tube to the pipe line flange.

In certain cases due to objection to the laying length of the long Venturi tube or possibly for reasons of cost, a tube referred to as a "short Venturi" is used. It differs from the long tube primarily in that the angle of the exit cone is much greater (normally 13 to 15 degrees total angle), thus making the overall length much less than a long tube of corresponding diameter which is justified on the grounds that a smaller head loss is created.

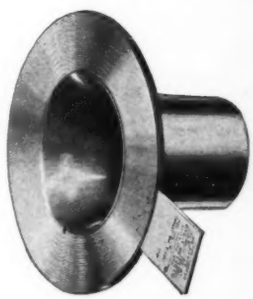


Fig. 3—Flow Nozzle

The majority of Venturi tubes are fabricated of cast iron and are provided with brass or bronze liners in the throat which are machined smooth within close tolerances. Small tubes of from 1 to 2 inches diameter are often made of brass or bronze throughout and the entire length of the internal surface may be completely machined all over. Very large ones have been constructed of concrete or steel plate with a cast iron throat section having a machined bronze liner, such as shown in Fig. 2.

Flow Nozzle

In many respects the flow nozzle (Fig. 3) may be considered to be a simplified Venturi tube. The entrance consists of a gradual curve of approximately one-quarter ellipse which leads the fluid smoothly into a short cylindrical throat section. Thus the discharge jet will have no contraction and will be the same diameter as the throat itself.

Installation of the flow nozzle is made by inserting it between a pair of pipe flanges. The high pressure upstream connection is usually made by tapping the pipe line approximately 1 pipe diameter back of these flanges, and the low pressure connection is made on the line at a point just opposite the throat section of the nozzle. For the measurement of water, air, sewage or

BAILEY METER COMPANY

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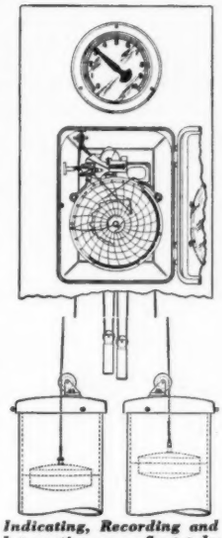
BAILEY METER COMPANY LIMITED, Montreal, Canada

METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

STANDARD BAILEY REGISTERS

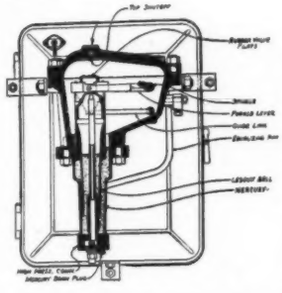
Open Float Tube Type—This register accurately measures the flow of sewage, sludge, dirty water or other liquids, using a Venturi tube, flow nozzle or orifice as the primary element. The external appearance of this indicating, recording and integrating register is shown in the installation photograph below. All parts are of stainless steel, copper, aluminum or other materials especially selected because of their ability to withstand the corrosive action of sewage, gas and sludge.

A high degree of accuracy is insured by a large float and a relatively large float motion applied through differential gearing and a cam to operate the register in direct proportion to the rate of flow. *Ask for Bulletin No.* 39.



Indicating, Recording and Integrating open float tube type Register.

Ledoux Bell Type—This register, operated by a mercury sealed Ledoux Bell is particularly well adapted to the measurement of sewage, sludge or water under pressure or where wide changes in hydraulic gradient are encountered. When applied to the measurement of sewage or sludge, settling chambers are used and a supply of fresh water is introduced so that a constant flow exists from the register to the Venturi tube. This is, of course, unnecessary when the meter is applied to clean water measurement.

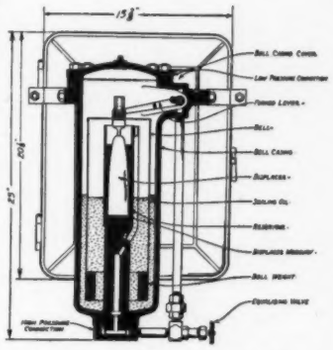


Section through flow mechanism of Ledoux Bell type Register.

In the water works field this register is particularly well adapted for use on discharge lines from centrifugal pumps, on gravity mains, on branch lines in distribution systems, and in filtration plants to measure raw water, clear water and wash water.

Suitable equipment can be furnished when it is desired to totalize the flow through several lines. *Write for Bulletin No.* 301.

Air Meters—These meters measure air flow in main lines and in individual lines to aeration tanks. It is desirable to meter both air and sewage to individual aeration tanks in order that they may be properly proportioned for best results in consideration of such factors as quality of raw sewage, detention, tank agitation and economical use of air.



Section through flow mechanism of Air Meter

This register differs from the Ledoux Bell type, previously described, only in the flow mechanism which in this case is designed to operate on a maximum differential of 8" of water. The motion of the oil sealed bell is transferred to the uniformly graduated chart by means of a forked lever, spindle and recording pen. *Described in Bulletin No.* 39.

Remote Registers—Bailey Telemetering systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey gages and registers.

Bailey control is fully automatic, dependable and exceptionally flexible. *Ask for Bulletin No.* 101.

Bailey Recorder—Controller.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

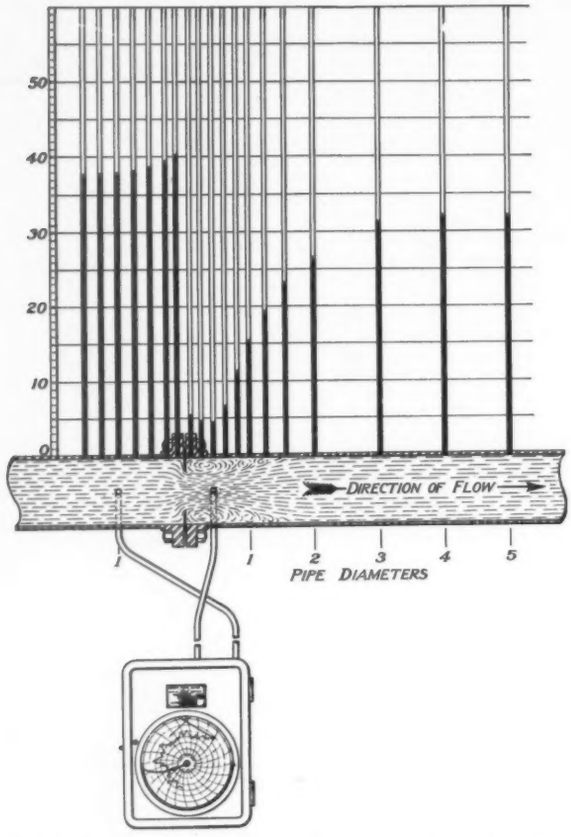


Fig. 4—Diagram of "Stream Lines" in a Fluid Flowing Through a Circular Concentric Orifice in a Pipe, Pressures Existing at Various Distances from the Orifice

sludge, flow nozzles are usually fabricated of bronze, the inside being very accurately machined.

Thin Plate Orifice

The thin plate, or sharp edged orifice, shown in Fig. 4 has been widely used for many years to measure the flow of fluids. In its simplest and most familiar form, the orifice is merely a hole in a flat plate which is clamped between flanges in the pipe line. It may be of 1/16 inch thickness or more, depending upon its diameter, and can be made of nickel, monel metal, steel or other suitable material. Flow meter literature abounds with results of thousands of experiments proving conclusively that the orifice operates on the same basic principles as does the Venturi tube and flow nozzle.

Referring to Fig. 4 it will be noted that there is a well-defined Vena Contracta (plane of greatest contraction) on the down-stream side of the orifice plate, just as is observed when the stream from a sharp edged orifice discharges into the open air. The pressure on the outlet side of the orifice varies along the length of the pipe with the velosity of the stream itself, the observed pressure being least (differential the greatest) when the connection is exactly opposite the Vena Contracta.

The location of the Vena Contracta remains constant regardless of the rate of flow for any one installation. It assumes a slightly different position, however, with different ratios of orifice diameter to inside pipe diameter. For a given ration, its relative position is independent of pipe size. The high pressure upstream tap is made at approximately one pipe diameter back of the orifice, and the low pressure tap is made exactly opposite the Vena Contracta. Some manufacturers recommend that the taps be close to and on either side of the orifice plate; in this case it is necessary to obtain the orifice plate and the flanges as an integral assembly.

Factors to Consider

Before a metering element is specified or selected for a given project, six factors must be taken into consideration if the most suitable arrangement is to be secured; namely (1) initial cost, (2) installation, (3) accuracy, (4) reliability, (5) pressure loss, (6) capacity change.

The above factors may not appear in their order of importance, for the item which is of primary importance for any one application will vary with conditions peculiar to that application.

1. Initial Cost

The initial cost (purchase price) of the primary element may vary within wide limits. Figure 5 illustrates the approximate relationship between present-day prices of long Venturi tubes, short tubes, bronze flow nozzles, and thin plate orifices. It will be noted that for a given size, the price decreases in the order named. Without question the orifice has a decided advantage with respect to initial cost, being approximately one-ninth that of a long Venturi tube of corresponding size.

In the larger sizes, say above 24 inches, it is also possible to obtain orifices at prices from 20 to 25 per cent lower than those shown, by specifying a steel orifice plate having a nickel insert. This insert has the orifice hole machined in it and thus the more expensive metal is used only where it is essential.

Very large Venturi tubes become cumbersome and expensive. On this account large tubes are frequently constructed of steel plate or concrete at its location and only the throat section is purchased from the meter manufacturer.

2. Installation

From the standpoint of ease of installation, the orifice or flow nozzle would be selected in preference to a Venturi tube. They need merely be inserted between a pair of flanges in the pipe line, but considerable care must be taken to center the element properly, to make the pressure connections at the correct locations, and to see that there are no protrusions left on the inside of the pipe line as the result of making the taps.

The Venturi tube being relatively larger and much heavier, more time and labor is required in the installation. If the pipe line is an existing one, it will be necessary to remove one or more sections of pipe and to provide filler pieces of the correct length so that the tube can be made a part of the line. On a new project, however, in comparing the cost of installing a Venturi tube a credit representing the cost of a section of straight pipe of the same length, which otherwise would be required if a flow nozzle or orifice were used, should be considered.

Since the pressure taps are an integral part of the tube, these can be assumed to be correctly placed.

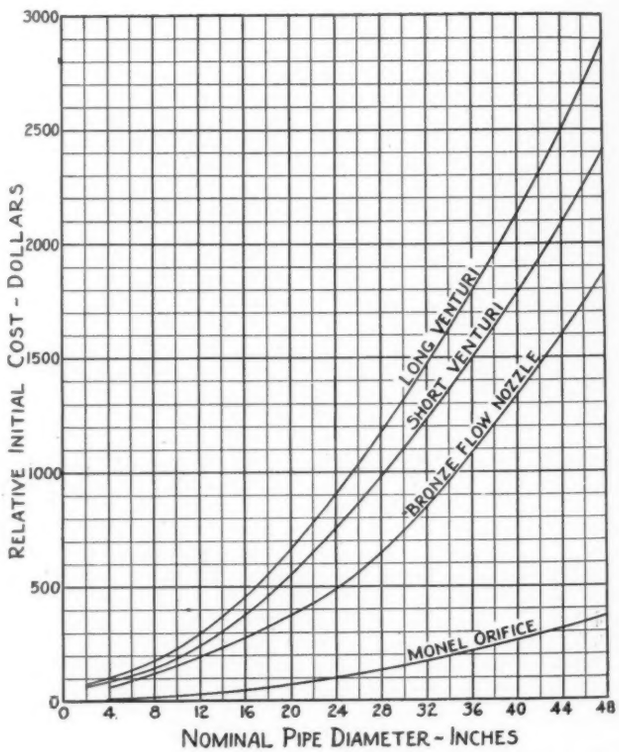


Fig. 5—Curves Showing the Approximate Purchase Prices (at Factory) of Various Types of Primary Elements. (The Curves for the Venturi Tubes Are Based on Weights Suitable for Use with Class A, B, and C Cast-Iron Pipe, and Do Not Include Handholes or Cleanout Valves Shown in Fig. 1)

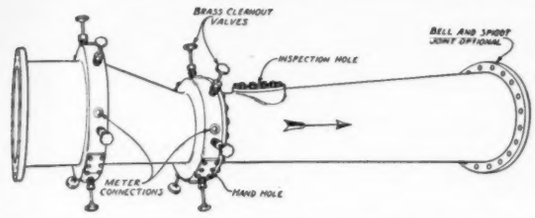


Fig. 6—Eccentric Type Venturi Tube for Sewage or Sewage Sludges

3. Accuracy

When installed under suitable conditions, the three primary elements are very nearly equal when compared on the basis of accuracy obtainable; namely, within 1 per cent of 100—plus or minus. Due to small inaccuracies introduced by the register mechanism, however, manufacturers normally extend a conservative guarantee that the reading will be within 2 per cent of 100 plus or minus. In actual practice the accuracy always falls well within the limits of the guarantee.

In order to insure accurate metering, all primary elements require a certain length of straight pipe preceding the location. For the Venturi tube, 5 to 10 pipe diameters are usually adequate. For the flow nozzle or orifice types this requirement is between 8 and 20 pipe diameters, depending on the ratio of orifice diameter to inside pipe diameter, and on the piping layout. Sometimes these requirements cannot be met due to the piping layout. It is under such conditions that the short Venturi tube occasionally proves most suitable because it is from 30 to 45 per cent shorter than the long tube of like diameter.

In order to preclude high readings on the registering device, the primary element should not be installed where the air or liquid flow is of a rapidly pulsating nature. Such a condition may be caused by water or sewage reciprocating pumps and by certain types of air blowers. It is sometimes possible to eliminate pulsations or dampen them materially but where pulsating flow is likely to be a problem this factor should be called to the meter manufacturers' attention; whereupon, specific recommendations will be made.

4. Reliability

It is essential that the primary element retain its accuracy after installation and that it also provide continuity of satisfactory service.

Screened sewages and sewage sludges present the greatest problem of measurement because of solid matter or gas which they contain. For this service the piezometer rings of the Venturi tube are equipped with cleanout valves (Fig. 1) which facilitate routine cleaning operations to maintain the openings free from obstructions. Connections should be made at top and bottom of each ring for venting accumulating gas or draining sediment. Handholes in each ring make the interior accessible.

At low velocities the throat section of the Venturi tube may act as a dam causing foreign material to settle on the bottom of the inlet cone and, thereby, affecting the accuracy. A condition of this kind can be largely avoided by the use of an eccentric Venturi tube (Fig. 6) which differs from the ordinary tube only in the eccentric shape of the converging and the exit cones. The fact that the bottom of the tube lies in one horizontal plane makes it easier for solid materials to be swept through the tube.

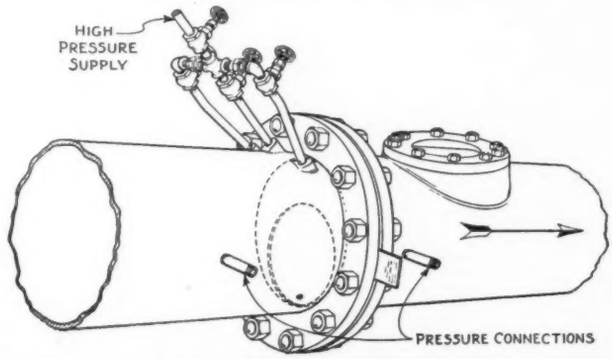


Fig. 7—Eccentric Type Orifice Installed in a Sewage Main, Illustrating an Arrangement for Washing Collected Materials Off the Face of the Orifice Plate

An installation of an orifice in a sewage line is illustrated in Fig. 7. Here also the eccentric type is of particular advantage in that solid materials pass through without obstruction. While there is even less chance of materials settling on the sharp edged opening than in the throat of a Venturi tube, there is a greater possibility of material collecting on the entrance side of the plate. For this reason it is desirable to provide a high pressure water supply into the pipe line (Fig. 7), for periodically washing off the face of the plate.

A common method for the prevention of plugged taps, and to keep the meter connections clean and free of deposits is to introduce a continuous trickle of clean water through the connecting pressure lines to create a slow current into the main pipe line.

Unless there is some especial factor involved, the flow nozzle should be avoided in metering sewage, because there is a tendency for materials to deposit in the throat section and to build up at the entrance. However, it has proved satisfactory where a

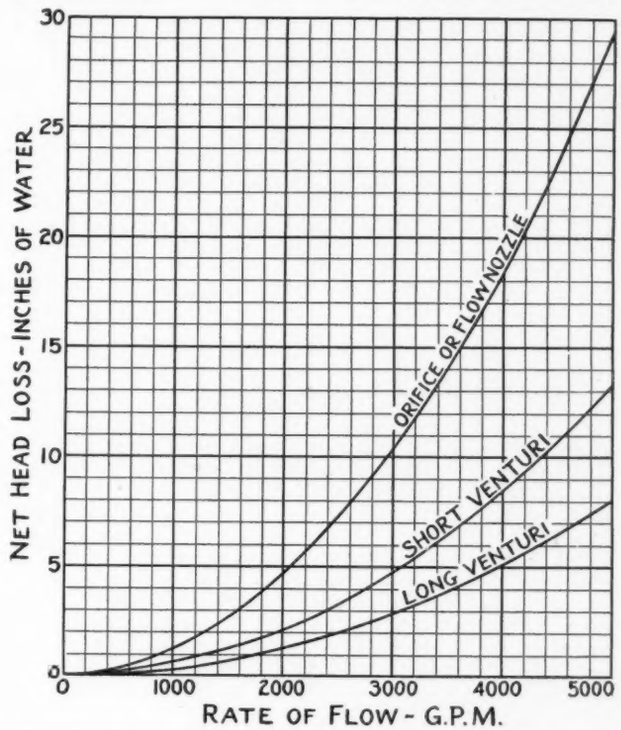


Fig. 8—Curves Showing the Net Differential Head Loss Created by Different Types of Primary Elements, Designed for a Maximum Differential of 53 Inches of Water, at a Maximum Capacity of 5,000 g.p.m., as Applied to a 20-Inch Water Main

means has been provided for flushing out the entrance and throat frequently.

Measurement of unscreened sewage should be avoided, except where there is no alternative, as for example when one community has its sewage treated in the plant of another municipality. The large heavy solids may cause greater wear and erosion on the primary element, and in the case of an orifice installation, there is the added danger of an object striking the plate with sufficient force to cause distortion.

Comparatively little attention is required for primary elements in air lines or fresh water mains, and all three elements will function indefinitely with practically no attention.

5. Pressure Loss

The differential head created by any of the three primary elements represents only a localized drop in pressure, most of which is restored upon resumption of normal flow a short distance following the primary element as is pictured in Fig. 4. It is important to hold head losses to a minimum, especially when capacities are large and available head is at a premium, or where pumping is involved and power requirements must be considered.

With the long Venturi tube, the pressure loss at any rate of flow is only approximately 15 per cent of the actual differential head produced by the element at that rate of flow, whereas with the short tube the loss is approximately 25 per cent.

The percentage loss created by orifices or flow nozzles depends

(*Continued on page* 168)

BUILDERS IRON FOUNDRY

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OMAHA, NEB., Pasol Engineering Co., P. O. Box 697.
ST. LOUIS, MO., Power Equipment Co., 4903 Delmar Blvd.
ST. PAUL, MINN., Commonwealth Electric Co., 417 Broadway.
SALT LAKE CITY, UTAH, Riter Engineering Co., 314 Kearns Bldg.
SAN FRANCISCO, CAL., Strout-Steffens Equipment Co., 357 Ninth St.
SEATTLE, WASH., Shibley Company, Inc., 1201 Textile Tower.
MONTREAL, P. Q., CAN., Drummond, McCall & Co., Ltd., Box 660.
TORONTO, ONT., CAN., Drummond Control & Metering Equipment Engineers, 454 King St., W.
VANCOUVER, B. C., CAN., Charles A. Moorhead, 1402 Bekins Bldg.
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PRODUCTS

Venturi Meters for Water, Sewage, Sludge, and Air; Orifice Meters for relatively less important lines; Venturi Rate of Flow Controllers; Loss of Head and Rate of Flow Gauges; Reservoir and Tank Elevation Gauges; Sewage, Sludge, and Air Flow and Ratio Gauges. Chronoflo Meters for Distant Metering, Summation of Meter Totals, Continuous Sludge Weighing, Chemical Feeding, Suction Well Level and Pump Control. %Proportioneers% Devices for Water and Sewage Treating and Chemical Feeding.

VENTURI

ENGINEERING SERVICE

Nearly fifty years of continuous service with the metering and controlling problems of water works and sewage plants have given Builders Iron Foundry engineers an unusual conception of the special requirements in these fields. Inquiries for recommendations covering the adaptation of standard metering and controlling devices are invited. Printed bulletins, illustrating and describing devices mentioned briefly in these pages, are available upon request.

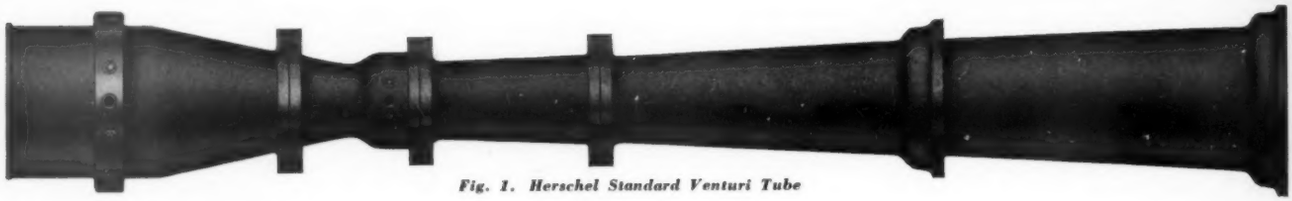

Fig. 1. Herschel Standard Venturi Tube

VENTURI METERS *for Water Works and Sewage Plants*

"VENTURI" Trade Mark Registered U. S. Patent Office

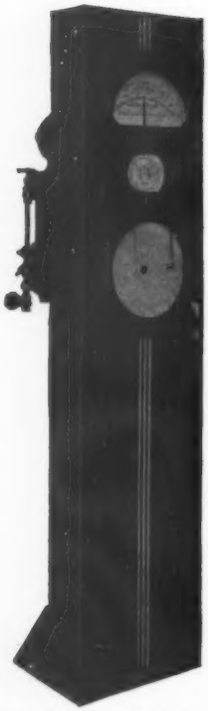

Fig. 2. Type M Register-Indicator-Recorder (Model D)

Venturi Tubes

The Herschel Standard Venturi Tube (Fig. 1) usually is made in two or more sections for water works' use. The throat section is bronze lined and accurately machined to correct diameter and established interior contour. For sewage and sludge measurement the tube is equipped with special vent cleaning valves and handholes. Flat invert tubes are available but experience indicates that they are rarely required since the relative high velocities and the unobstructed passageway of the standard Venturi shape prevents deposition.

S-4 Design Tubes are somewhat shorter than Standard Tubes. The non-interchangeability of throat sections and somewhat higher head loss offset, somewhat, their price advantage.

Control valves, usually of the cone type, are frequently placed in the outlet cones of Venturi Tubes, effecting important savings in valve cost without sacrificing accuracy.

Venturi Metering Instruments

Model D, Type M Register-Indicator-Recorder is the latest in the line of well known Type M Venturi Instruments which have earned an enviable reputation for simplicity, sturdy construction, and maintained reliability of performance. The illustration (Fig. 2) shows the modern appearance of the Model D, in harmony with present day water works and sewage plant architecture. **Indicator dial** is at eye level with uniformly spaced scale; **Totalizer,** is of same general design as former Type M's but enlarged and with important mechanical improvements; **Recording Chart** is 12" in diameter and furnishes a permanent record of flow variations. All dials are of translucent white pyralin, engraved with black graduations and lettering and effectively illuminated.

The Type M Register is connected to the Venturi Tube by two pressure pipes for normal heads; by cable connection from floats or from detached mercury wells for low heads. With special connections, fairly dense sludge can be measured. For air a differential oil well is substituted for the standard mercury wells.

VENTURI RATE OF FLOW CONTROLLERS FOR WATER

Efficient filtration requires the maintenance of a constant rate of flow through the filter bed. This is automatically accomplished by the Venturi Rate of Flow Controller, installed in the effluent line, which gradually opens as the sand friction of the bed increases. The Venturi Tube, as the primary element of this device, provides the highly desirable combination of accurate rate control and small loss of head.

Several designs of Venturi Controllers are available: **Direct Acting** (Fig. 3) has a double disc, balanced rotary control-valve directly actuated by a diaphragm which is pressure-connected to the inlet and throat of the Controller Tube.

Design "A"—employs a gate valve with specially-shaped seat. Venturi flow differential actuates a diaphragm pilot valve unit admitting water pressure to a hydraulic piston which positions the control valve automatically.

Design "B" (Fig. 4) uses a double butterfly valve of rectangular section. This valve is positioned by a hydraulic piston through a differential diaphragm pilot valve unit connected to the inlet and throat of the Venturi Controller Tube.

Fig. 3. Venturi Direct-Acting Controller

Provision is made in all types for conveniently setting the desired rate.

Master Controllers—In large plants it is often desirable to set the rate of all of the individual effluent controllers from a central point or to control automatically from clear well levels. Builders Iron Foundry has designed and furnished numerous master controllers, designed for the particular operating characteristics of each installation.

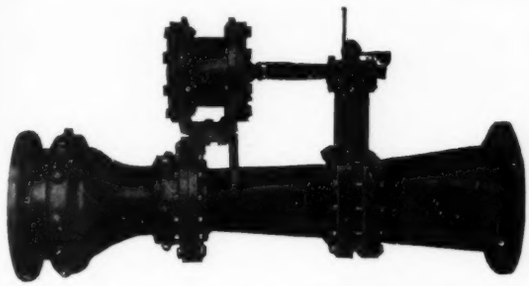

Fig. 4. Venturi Controller—Hydraulically Operated

BUILDERS WATER WORKS GAUGES

The gauge illustrated (Fig. 5) is typically modern, in keeping with modern filtration plant design. **Rate of Flow Gauges** respond to differential pressures caused by flow through Venturi effluent controllers. **Loss of Head Gauges** show the difference in elevation between the water on the filter and head in the effluent pipes. **Water Level Gauges** are float and cable actuated; they show level of water in basins, reservoirs, etc., in feet or elevation.

The internal mechanism of Builders Gauges is of bronze, aluminum, and other corrosion resisting materials. The exterior is neatly finished in black with chromium trim. Numerous designs are offered, in single and double dial indicating and recording types. Large illuminated gauges or gauges of special design to conform to plant decoration, can be supplied.

Fig. 5. Indicating Recording Gauge

FLOW AND RATIO GAUGES FOR SEWAGE PLANTS

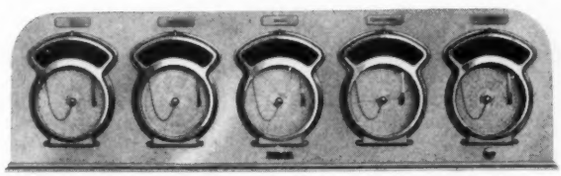

Fig. 6. Five Dial Air, Sewage, and Sludge Flow and Ratio Gauge

The trend in modern sewage plant operation is toward complete instrumentation. To illustrate, the five dial gauge (Fig. 6) shows:

1. Air to aeration tank
2. Ratio of air to sewage: "Cubic feet of free air per gallon of sewage"
3. Raw sewage from primary tank to aeration tank
4. Ratio of returned sludge to raw sewage, reading in per cent
5. Sludge returned to aeration tank

FLOW MEASUREMENT: Flumes, Nozzles, and Weirs

Builders Iron Foundry standard registers, adapted for float actuation, furnish a highly satisfactory means of indicating, recording, and totalizing the flow through Parshall Flumes.

These Flumes have proved well suited for the measurement of flow through channels over a comparatively wide capacity range. They can be built almost entirely of concrete, with practically no limit as to size and capacity.

KENNISON NOZZLE (Fig. 7)—has attracted favorable attention for the measurement of sewage from districts into sewer systems and for activated sludge from primary settling tanks. Builders Iron Foundry recording instruments used with these nozzles can be graduated directly in rate of flow units.

Fig. 7. Kennison Nozzle

Standard Weirs are occasionally found useful under certain conditions measuring total incoming flow, plant output, bypassed storm flow, etc. Metering instruments for indicating and recording such flow are available.

CHRONOFLO METER USES

("Chronoflo" Trade Mark Registered in U. S. Pat. Office)

DISTANT FLOW METERING

Chronoflo Meters have found a broad application in bringing to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position, and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Indicating and Recording Instruments.

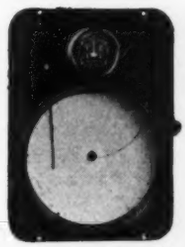

Fig. 8. Chronoflo Register-Recorder

RESERVOIR AND TANK ELEVATION GAUGES

Chronoflo Indicating and Recording Gauges installed, for instance, in the water works office downtown, continuously indicate and record level in outlying reservoirs, tanks, or standpipes, allowing efficient operation of pumping stations and eliminating the necessity of taking such measurements manually. Any number of instruments can be actuated from a single transmitter and installed in locations convenient to the operating and supervisory staffs.

DISTANT TRANSMISSION AND SUMMATION

In Metropolitan Water and Sewage Districts serving a group of towns and cities it is frequently desirable to add the totals of various individual meters installed in widely separated locations to determine the grand total flow. The Chronoflo Meter is peculiarly adapted for such services. Fig. 9 shows a Chronoflo summation layout in which readings of six Venturi Meters of varying capacities are totalled.

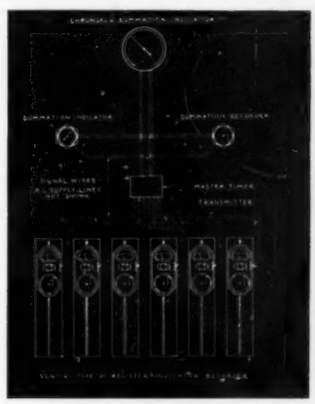

Fig. 9. Totalizing Readings of Six Venturi Meters

CONTINUOUS SLUDGE WEIGHING

In many sewage plants efficiency of operation is determined by weight of filter cake being carried from rotary filters to final disposal. A recent development is the attachment of a special Chronoflo Weight Transmitter to a Toledo Automatic Scale which integrates on a counter and records on a continuous chart the total amount of material which has passed during any required period. The Chronoflo Totalizing and Recording Instrument for weight of conveyed material can be installed nearby or at any distance from the scale.

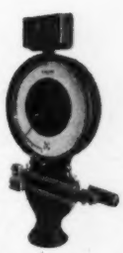

Fig. 10. Transmitter on Scale

RAW SEWAGE SUCTON WELL LEVEL AND PUMP CONTROL

Under some conditions automatic control of sewage treatment plants should be provided. Such control must be designed for each particular application. Builders Iron Foundry engineers are in a position in work with sewage plant designers in providing Venturi and Chronoflo control devices for this service.

upon the ratio of the throat diameter to the internal pipe diameter—the smaller the throat or orifice the greater the percentage loss. When designed for identical conditions of capacity, etc., the percentage loss will be virtually the same for both the orifice and the flow nozzle.

As a typical example, assume that a water meter operating on a maximum differential head of 53 inches of water is to be applied to a 20-inch main and to have a maximum capacity of 5,000 g.p.m. The loss of head created at maximum flow by the various elements as shown by the curve in Fig. 8 would be:

Long Venturi, 7.95 in. water (.15 × 53).

Short Venturi, 13.25 in. water (.25 × 53).

Orifice or Flow Nozzle, 29.15 in. water (.55 × 53).

With a flow of 2,500 gallons per minute (½ of maximum) the losses produced would be only ¼ of these values, because the differential head varies proportionately to the square of the rate of flow.

Although the curves of Fig. 8 apply only to the specific example, it can readily be seen that conditions exist where, by use of a Venturi tube, the reduced cost of pumping over a short period of time will more than offset the higher initial cost of the Venturi tube.

5. Capacity Change

An existing meter installation may at some time require an increase in maximum capacity to meet the requirements of increasing quantities of fluid handled by the system. This may be accomplished in three ways—either by providing a new primary element, by modifying the old one to handle the larger capacity, or by increasing to the required extent the maximum differential head with which the register functions.

With the Venturi tube, the first two methods are costly, particularly in the larger size and therefore the register differential is usually increased. It should be borne in mind, however, that with this method, at rates of flow exceeding the original maximum capacity the pressure loss increases as the square of the flow.

When an orifice or flow nozzle constitutes the primary element, a new one can usually be installed at reasonable cost. Since such a change necessitates a larger orifice the pressure loss will be lower than for the original installation, notwithstanding the increased flows handled. This naturally cannot be accomplished in cases where the primary element originally installed is already near the greatest ratio for which it can be designed. It is necessary then to increase the differential head of the register and suffer the head loss entailed or else to provide a duplicate installation on a parallel twin line.

Knowledge of the principles described and intelligent consideration of the six factors outlined above will aid materially in obtaining primary elements which are most suitable for the particular project from the standpoint of both satisfactory operation and cost.

Final decisions can be made only when complete details and figures are available pertinent to the specific problems under consideration. Therefore, it is important to supply meter manufacturers with as complete data as possible concerning each contemplated meter installation, such as the type of fluid, maximum capacity, pipe diameter, pressure, and a dimensioned sketch of the piping layout.

Part II—Secondary Elements

The secondary element of large meters (more commonly known as a register) is actuated by the differential pressure and, through mechanical or electrical means, converts such into records or indications of the rate of flow. In addition a totalization of the weight or volume passing through the line is registered.

Although there are many types and makes of registers, they depend upon only a few basically different types of mechanisms designed to utilize the differential head. These form the basis for much of the following discussion concerning secondary elements as applied to various services.

Because of the extensive use of the Venturi tube as a primary element, it is desirable to have the register designed so that its capacity can be changed by increasing the maximum differential head upon which it functions without altering the primary element or connecting lines, thereby eliminating expensive replacement of tubes.

Registers may be divided into two general classes of differential translating mechanisms; (1) the open float tube type, and (2) the pressure chamber type.

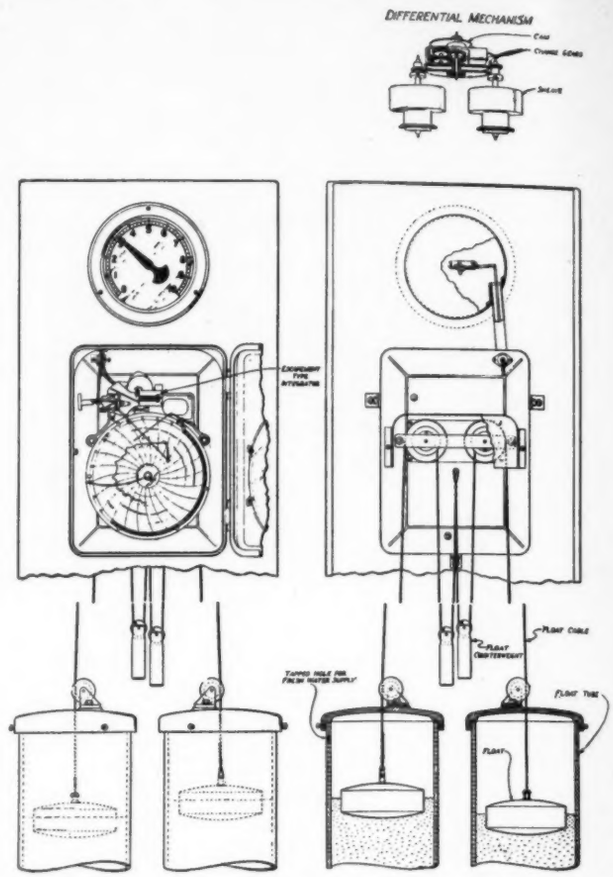

Fig. 1.—An example of the open float tube register for the measurement of sewage, sludge, and dirty water. (Courtesy of Bailey Meter Co.)

The Open Float Tube Register

The open float tube register is used only where the hydraulic gradient is relatively low and where changes in it are not severe. It is most extrensively used in metering sewages and sludge.

One example of the open float operated register is shown in Fig. 1 and a diagrammatic installation of this register, Fig 2, illustrates its position relative to the float tubes, and the Venturi tube.

One float tube is connected to the inlet and the other to the throat of the Venturi tube by pressure piping so that the water level in each tube will rise to a height corresponding to the pressure existing in the Venturi tube at the point where the connection is made.

The rate of flow, represented by the difference in levels of the floats in the float tubes, is transmitted to the register by cables which are attached to sheaves as shown in Fig. 1. These cables operate the differential mechanism and square root cam which in turn transmit the rate of flow to the recording pen, the integrator and the indicator. A square root cam is employed to translate the differential into terms of flow so that the pen motion will be directly proportional to the rate of flow.

Another function of the differential gearing system is to automatically compensate for variations in line pressure or hydraulic gradient. This mechanism is designed so that if both floats rise or fall an equal amount there will be no change in the position of the operating cam. However, if there is a change in the difference between the levels in the float tubes, this change immediately operates the square root cam which in turn moves the recording pen to a new position, thereby registering the variation in rate of flow.

The maximum capacity of this float operated register can be altered by simply changing two sets of gears in the differential mechanism. This feature is provided to eliminate excessive costs for the replacement of the Venturi tube with modern equipment; wide variations in capacity can be obtained without removing the primary element from the line or disconnecting the meter in any way.

The register itself is mounted on the operating floor immediately

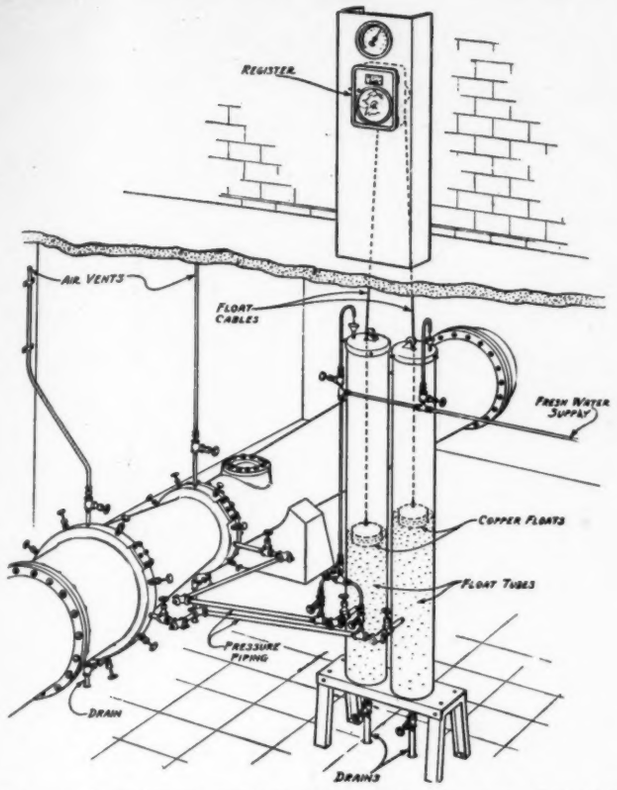

Fig. 2.—An approved method of installing the open float tube register for the measurement of sewage or sludge. (Courtesy of Bailey Meter Co.)

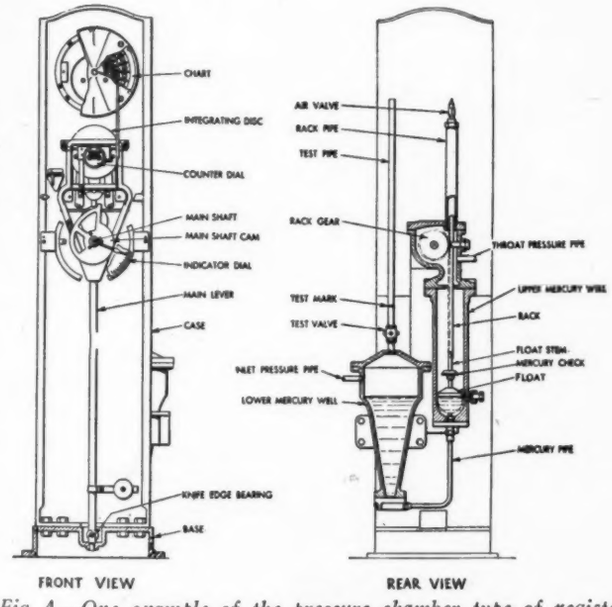

Fig. 4.—One example of the pressure chamber type of register using a float. (Courtesy of Builders Iron Foundry.)

above the float tubes. Cables are strung from the sheaves to the copper floats in the float tubes. This cable system is counterweighted as shown in Figure 1 so that there is an even tension on the float cables at all times. The float tube covers are provided with small pulleys to guide the copper floats in the center of the tubes without undue friction in the mechanism.

A satisfactory method of installing the float operated register is represented by Fig. 2. The float tubes are usually made of 10-inch cast iron pipe and should be located directly below the register and as close to the Venturi tube as conditions will permit. A constant supply of fresh water is slowly introduced into the float tubes so that the water flows from the tubes out through

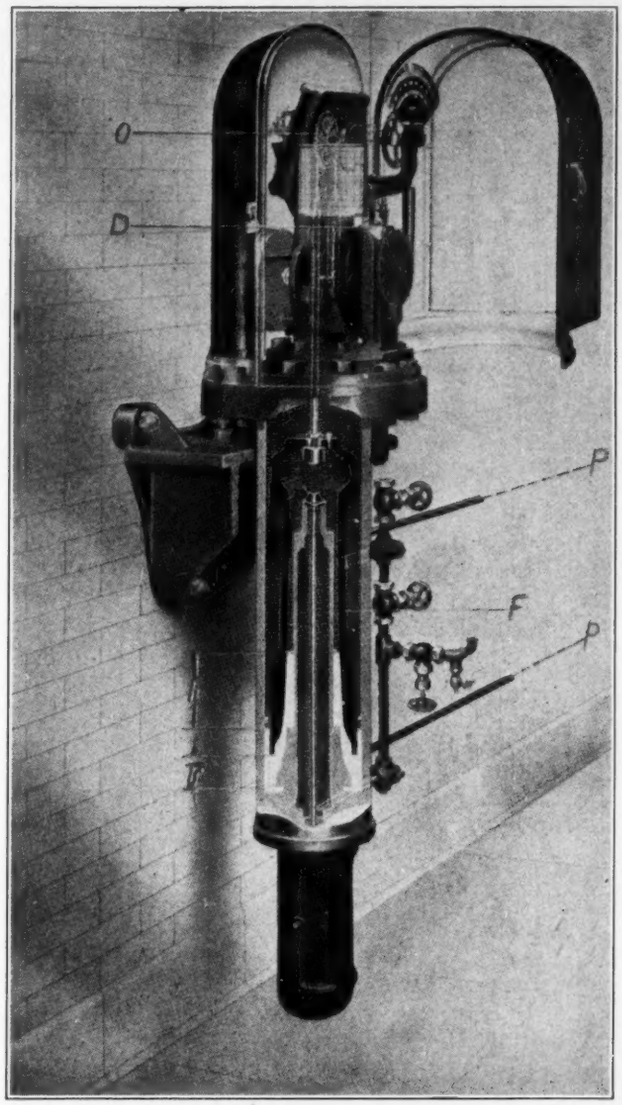

Fig. 3.—An example of the pressure chamber type of register using a mercury sealed bell. (Courtesy of Simplex Valve and Meter Co.)

the pressure piping to the Venturi tube thereby minimizing the accumulation of solid matter in the system. Provision is also made for flushing out the pressure piping with clean water under pressure, and also for cleaning the inside surface with a brush or "ram" should such be necessary. The float tubes are fitted with shut-off valves and drain connections.

The piping connecting the Venturi tube with the float tubes is sloped (grade of ½-inch or more per foot) to prevent air or gas from becoming trapped in the piping and causing false levels to exist in the float tubes. The piping should be of 1-inch or larger copper or red brass pipe joined together with crosses at all changes of direction so that it may be rammed or brushed clean by removing the pipe plugs from each end of the run to be cleaned. Gate valves should be used on these lines instead of globe valves because they open to provide a free and unrestricted passage through the pressure piping, which is necessary to facilitate cleaning.

The fresh water supply piping may be readily constructed of copper tubing and compression fittings. Copper tubing of ½ inch diameter usually furnishes sufficient fresh water for the sight feeds.

Vents, leading to a point above the maximum hydraulic gradient, should be provided at the inlet and throat rings of the Venturi tube as shown in Fig. 2. To insure continuous venting, these vents should be left open at all times except when flushing the piezometer rings.

The "standard" arrangement of register and float tubes (Fig.

(*Continued on page* 172)

SIMPLEX VALVE & METER COMPANY

6749 Upland Street, Philadelphia, Pa.

SIMPLEX REPRESENTATIVES

ATLANTA, GA., W. D. Taulman, 179 Spring St., S.W.

BOSTON, MASS., Hayes Pump and Mchy. Co., 125 Purchase St.

CHARLOTTE, N. C., T. C. Heyward, Independence Building

CHATTANOOGA, TENN., E. N. Shelton Co., 1010 Georgia Ave.

CHICAGO, ILL., A. F. Barron, 59 East Van Buren Street

CLEVELAND, OHIO, A. MacLachlan Co., 1740 E. 12th St.

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LOS ANGELES, CALIF., Ralph W. Lawton, 1115 So. Hope St.

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NEW YORK, N. Y., W. K. Sowdon, 342 Madison Avenue

OMAHA, NEBR., O. F. Barklage & Co., Keen Hotel Bldg.

PITTSBURGH, PA., Ross Mechanical Supply Co., 435 Water St.

ROCHESTER, N. Y., A. L. Covill, 1041 Granite Bldg.

SALT LAKE CITY, UTAH, Denver Fire Clay Co., 157 W. Second South Street

SAN FRANCISCO, CAL., Water Works Supply Co., 501 Howard St.

SEATTLE, WASH., H. D. Fowler, 419 Smith Towers

TULSA, OKLA., McGregor & Thilenius, P. O. Box 1141

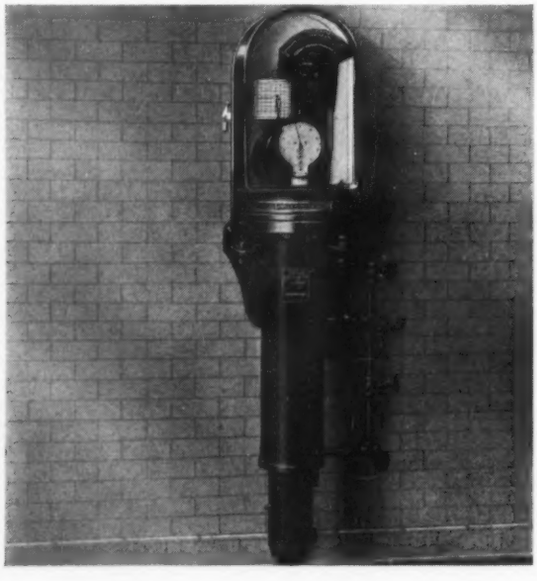
TORONTO, ONT., CANADA, Simplex Valve & Meter Co. of Canada, Ltd.

PRODUCTS:

Simplex Venturi Type Meters for Measurement of Water, Sewage, Sewage-Sludge, and Air; Filter Rate of Flow Controllers; Loss of Head and Rate of Flo Gauges; Simplex Pump Casing Tap Meters; Pilot Tubes and Manometers; Portable Pitot Recorders; Water Level Gauges; Air Release and Air and Vacuum Valves; Proportional Chemical Feeding Devices; Sewage Aerators; Rotary Distributors; Hydraulic Equipment of Special Design; Sand Expansion Indicators.

SIMPLEX METER REGISTERS:

Primarily designed for use with Venturi tubes, Simplex meter registers are also used with Simplex pitot rods, orifice plates, and pump casing taps, as primary actuating devices. They are designed for use in measuring liquors and gases under all pressure conditions and are particularly fitted for the measurement of raw water, wash water, filtered water, raw sewage, screened sewage, mixed liquor, raw sludge, digested sludge, and air.



Noted for their ability to operate under small Venturi heads, Simplex meter registers measure accurately flows corresponding to water differentials of from ⅛" and up. Particularly designed to measure accurately the slightest change in rate of discharge, Simplex meters can be furnished to either indicate, record, or totalize the flow, or in any combination of these functions. Simplex meter registers of standard form are also furnished for the measurement of discharge through egg-shaped flumes, Parschall Venturi flumes, weirs, and other forms of primary devices wherein a free-falling discharge is present.

Simplex meter registers can be arranged for mechanical totalization of the flow from any number of individual instruments whereby the total flow can be transmitted to either a large dial indicator, a total flow recorder, or a complete summation meter of the indicating, recording, and totalizing type.

Simplex meter registers can be operated by air differentials, thereby preventing the entrance of any sewage, sludge, or corrosive liquors into the metter float cylinder.

Each instrument has included with it as a standard item of equipment a device whereby its accuracy and sensitivity can be checked at any time during its period of service.

SIMPLEX FILTER RATE OF FLOW CONTROLLERS:

Provide an efficient device for the operation of gravity or pressure filters which maintain the rate of discharge through the bed at a constant, regardless of variations in pressure or water level, utilizing as an operating means only the pressure effect of the water flowing through the filter effluent line.

Simplex Controllers operate with the lowest obtainable head losses when wide open; attain the highest degree of accuracy in control without the use of compensating mechanisms; and are capable of covering the largest possible ratio from maximum to minimum rates with any given size of unit; avoid the use of any

electrical mechanisms in their operation; start quickly from a wide open position, and take the rate for which set in less than fifteen seconds.

The Simplex, direct-acting controller is arranged for either straight-through, right, or left-hand outlet as may be desired, and can be installed in either a vertical or horizontal line, as required.

Simplex rate of flow controllers can be equipped with the Simplex master control system, whereby the rate through the entire battery of filter units can be changed from a single point on the operating floor or wherein the rate through each controller unit will vary with the elevation of water on the filter or in the clearwell.

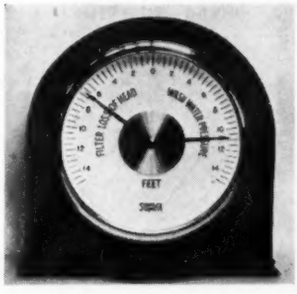
Simplex rate controllers can also be arranged with means for changing the rate from the operating floor.

SIMPLEX FILTER GAUGES:

These may be furnished in any combinations of indicating, recording, and totalizing rate of flow with indicating and recording of lost head.

Simplex gauges are of the mercury float operated type, wherein the Simplex bell-shaped float is used to provide uniform graduations of flow on both indicating dial and recording chart.

Similar in design to the Simplex meter register, Simplex filter gauges respond to the slightest variations in rate or loss, and will measure accurately over the entire range with an average error not exceeding ± 3%.



Simplex rate of flow gauges have been arranged for totalization, wherein there is shown on a single 24" diameter dial gauge, located on the operating floor, the total flow through any or all of the controller units. There can be mechanically linked to the total flow indicator, chemical feeders or chlorinators, thereby providing accurate control of the chemical dosage at all time during the plant run.

Also available for measuring the depth of water in clear wells, wash water tanks, sedimentation basins, are Simplex water float operated gauges, which can also be furnished in any combination of the indicating and recording types.

Simplex gauges are accurate, dependable, and easily installed—a high-grade quality product, made with precision and care.

SIMPLEX AIR RELEASE AND AIR AND VACUUM VALVES:

In the design and operation of large steel pipe lines flowing under gravity, consideration should be given to the possibility of collapse, in case, for any reason, the internal pressure is reduced below that of atmosphere.

Simplex Air and Vacuum Valves are used on large mains, where there is danger of collapse, due to vacuum; the valve breaking the vacuum, thus preventing collapse. They facilitate the filling of the main, since wide open until full of water.

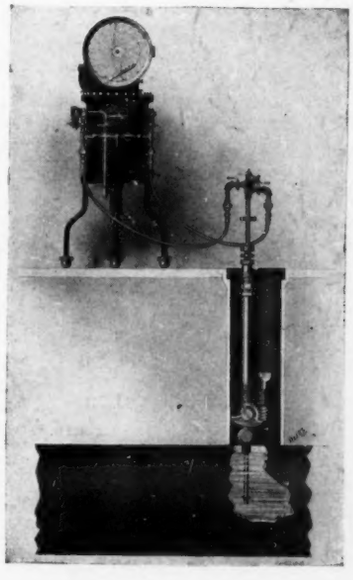
Simplex Automatic Air Release Valves have been designed to release, automatically, accumulations of air. They possess the merits of continuous operation without attention; simplicity; compactness; accessibility, and low cost, all of which are proved by over fifteen years' satisfaction to many users. Located on the high portions of the line, they insure automatic venting of the line and a continuous flow.

SIMPLEX PITOT TUBE RECORDERS:

For use with Simplex Round or Flat Pitot Rods —afford not only a record of velocity but can be furnished with pressure elements to give simultaneous readings of velocity and pressure.

This equipment may also be used for Water Waste Surveys or for conducting water flow investigations.

Indispensable to water works engineers for determining character of the flow in the mains of the distribution system.



SIMPLEX SEWAGE EQUIPMENT:

The Simplex Valve & Meter Company is the Eastern distributor for the Simplex Ejector & Aerator Corporation, Chicago, manufacturers of a complete line of sewage treatment equipment, including screens; clarifiers; mechanical surface aerators, for activated sludge plants; revolving sewage distributors; ejectors; and, as well, the newly-developed Simplex Aero-Filter. Competent engineers are at your service to assist you in your problems.

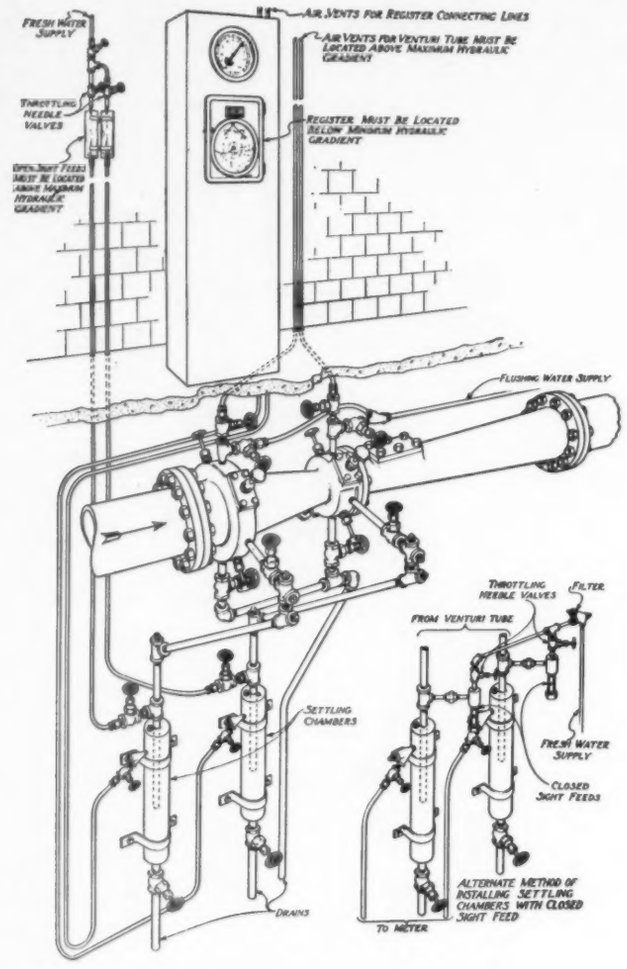

FRESH WATER SUPPLY
THROTTLING NEEDLE VALVES
OPEN SIGHT FEEDS MUST BE LOCATED ABOVE MAXIMUM HYDRAULIC GRADIENT
AIR VENTS FOR REGISTER CONNECTING LINES
AIR VENTS FOR VENTURI TUBE MUST BE LOCATED ABOVE MAXIMUM HYDRAULIC GRADIENT
REGISTER MUST BE LOCATED BELOW MINIMUM HYDRAULIC GRADIENT
FLUSHING WATER SUPPLY
THROTTLING NEEDLE VALVES
FILTER
FROM VENTURI TUBE
SETTLING CHAMBERS
FRESH WATER SUPPLY
CLOSED SIGHT FEEDS
ALTERNATE METHOD OF INSTALLING SETTLING CHAMBERS WITH CLOSED SIGHT FEED
DRAINS
TO METER

Fig. 5.—A recommended method of installing the pressure chamber register, whether bell or float type, for the measurement of sewage or sludge. (Courtesy of Bailey Meter Co.)

2) is not satisfactory in cases where the maximum hydraulic gradient rises above the register location. For installation under such conditions, the register may be mounted at an elevation *below* the float tubes and motion of the floats can be transferred to it by running the cables over a suitable arrangement of pulleys. Conditions of this kind can also be satisfactorily handled by the pressure chamber type of register and the sight feed system described in the following section.

Pressure Chamber Register

Where line pressures are high, or when wide changes in the hydraulic gradient are to be encountered, the pressure chamber operated register should be used. With this type of meter, the pressure piping from the primary element is connected directly to the flow mechanism of the register which contains either a bell or a float.

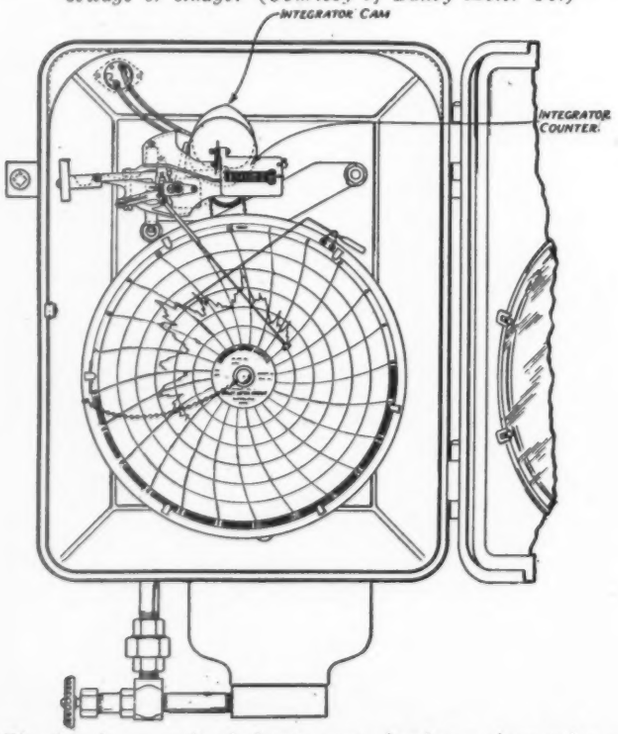
One example of a pressure chamber register using a bell is shown in Fig. 3. The actuating mechanism, a hollow float of bell shape which is sealed in mercury, is subjected on the outside to the higher pressure from the approach side of the primary element and on the inside to the lower pressure. The float is shaped so that the resultant downward movement, from its position at zero differential head to the position of equilibrium, is directly proportional to the instantaneous rate of flow through the primary element.

Movement of the float is transmitted to a sheave, usually by a flexible cable provided with a counterweight and sheave clamp. The sheave is fixed to a shaft carried on pivot bearings. After passing through the stuffing box, the shaft further supports the flow pointer, the recording pen, and the integrating mechanism.

An example of the float type of pressure chamber register is illustrated in Fig. 4. The pressure connections from the primary element are connected to the two sides of a mercury U-tube, the higher pressure being connected to the tapered well, and the lower pressure to the well containing the float. As the rate of flow varies through the primary element, the mercury level in the U-tube will also vary, thus raising or lowering the float. This motion, through the rack and gear, provides the motive power for operating the indicating, recording, and integrating mechanisms.

The specially tapered well of the U-tube partially extracts the square root of the differential, and the remainder of the function is converted by a shaped cam in the register so designed that actual motion of the recording pen and indicator becomes directly proportional to the rate of flow.

One method of installing the pressure chamber type of register in accordance with good engineering practice is represented by Fig. 5. Foreign matter is prevented from entering the register flow mechanism and connecting piping by the open sight feeds and the settling chambers. The sight feeds cause fresh water to



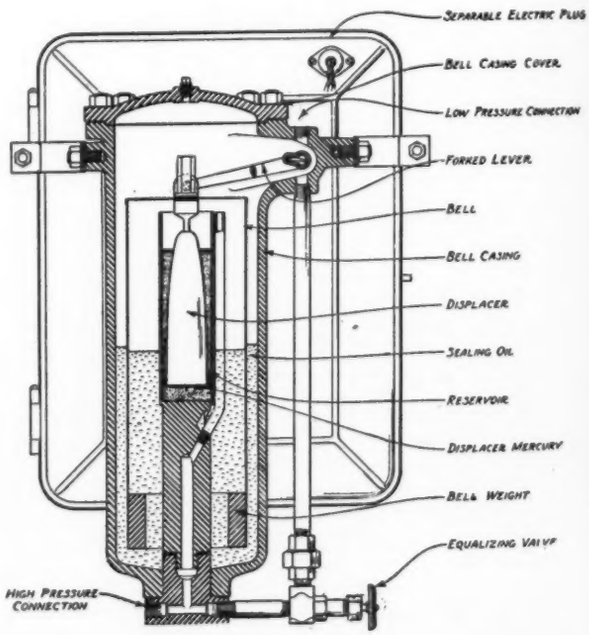


Fig. 6.—An example of the pressure chamber register using an oil sealed bell for measuring air. (Courtesy of Bailey Meter Co.)

flow from the settling chambers back through the pressure piping to the piezometer rings of the Venturi tube. This flow opposes the tendency of solid matter to work into the piezometer rings and pressure piping. The settling chambers, installed between the pressure piping and the copper tubing connecting lines to the register, collect and permit disposal of any solid matter which may work into the piping.

The pressure piping is of 1-inch or larger brass or copper. To facilitate cleaning, crosses are used for fittings, as shown in the illustration. From the settling chambers to the register, ½-inch copper tubing and fittings are suitable.

Open sight feeds are recommended in order to eliminate the possibility of water contamination by a direct cross-connection between the fresh water supply and the sewage system. If preferred, or if the maximum hydraulic gradient is too high to permit the convenient use of open sight feeds, closed sight feeds (see Fig. 5) can be used provided that the water supply to which they are connected is wholly independent of the city water. In some cases, an intermittent type of flushing system is used which utilizes city water. This however, requires the attention of an operator to establish and maintain the cross-connection and disconnect it when manual attention ceases. A flushing connection to the inlet and throat rings of the Venturi tube is also recommended.

When it is necessary to measure the flow through a line in which the hydraulic gradient varies over a wide range, and at the same time to locate the register above the minimum hydraulic gradient, the flow mechanism may be detached from the register and mounted at a lower elevation than the registering instruments. In this case, the movement of the flow mechanism is transmitted to the indicating, recording, and integrating devices by means of flexible cables.

Air Meters

For the measurement of air for aeration in the activated sludge type of sewage treatment plant, or mixing and partial aeration in chemical treatment, the translating mechanism of the register must of necessity function with a small differential head inasmuch as the static pressure of the air itself is low. Under these conditions the pressure chamber type of register is applied, but the sealing fluid usually is oil instead of mercury.

One type of meter used with air is represented in Fig. 6. The differential pressure is applied across the oil sealed bell to which is attached a specially shaped displacer which changes its immersion in mercury as the bell rises and falls with changes in differential pressures. The large size of the oil sealed bell permits operation on very low differentials, yet retaining ample power for the operation of the registering devices. The shaped displacer becomes directly proportional to the rate of flow.

Installation of air meters is a relatively simple task since ½-inch copper tubing with compression fittings, or brass pipe and fittings, may be connected from the primary element directly to the pressure chamber of the register. Settling chambers are not necessary.

Water Meters

For the measurement of clear water the pressure chamber register as described for sewage measurement is recommended. These meters are in service in the water works field on discharge lines from centrifugal pumps, on gravity mains, on branch lines in distribution systems, and in filtration plants to measure raw water, clear water, and wash water and rates of filtration.

The installation of the register when applied to clean water is as simple as that of an air meter. Direct connections from primary element to pressure chamber may be made with ½-inch copper tubing or brass pipe. Settling chambers are not usually necessary, nor are the sight feed supply systems.

Register Instruments

The register instruments contain relatively simple mechanical or electrical devices which react in accordance with the movements of the flow mechanism to provide indications, chart records, and an integration.

It is advantageous if these instruments are designed so that additional equipment can be easily installed in them at any time for commanding the operation of auxiliary registers, signal devices, and controllers. This feature simplifies expansion of the services rendered by the main register such as operation of remote registers, totalization of flow through two or more influent lines to continuously indicate the capacity at which the plant is functioning. Likewise, for the automatic control by flow or the ratio of quantity of sludge returned to the aeration tanks.

PHIPPS & BIRD, INC.

LABORATORY APPARATUS AND CHEMICALS

915 East Carey Street **RICHMOND, VA.**

PHIPPS & BIRD LABORATORY MIXER

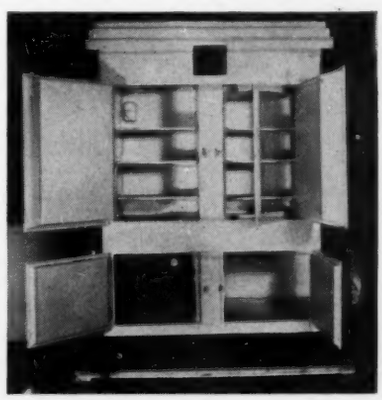
The Phipps & Bird Mixer is designed for alum floc formation determination in treated water. The speed of the paddles may be varied from 15 r.p.m. to 110 r.p.m.

These are the standard units:

Three unit size
Four unit size
Five unit size
Six unit size

COMBINED TWENTY DEGREE INCUBATOR AND REFRIGERATOR

The Allied Twenty Degree Incubator and Refrigerator consists of two insulated chambers. In the left hand chamber a temperature as low as five degrees Centigrade (forty degrees Fahrenheit) may be maintained. In the right hand chamber, a temperature of twenty degrees plus or minus one degree Centigrade is maintained. One of the chambers in the lower part houses the refrigerating unit and the other may be used for storage purposes. This is used extensively for B. O. D. determinations.



We also manufacture Solution Feeders, Baldwin Alumina Outfits, Fermentation Tube Supports, and are distributors of Laboratory Apparatus and Chemicals

THE PARSHALL FLUME FOR MEASURING SEWAGE FLOWS *

It's Theory and Applications

BY NORMAN C. WITTWER

Sanitary and Hydraulic Engineer, Rahway, N. J.

Most sanitary engineers and sewage works operators are familiar with the conventional devices for measuring and recording the flow of water. These comprise the various types of over-fall weirs and the Venturi tube. The Venturi flume in its present form as improved by Parshall[1] is not so generally known, and has not been used to any great extent in connection with sewerage practice.

However, for measuring the flow of water or sewage in open channels, this device has several distinct advantages:

(1) The accuracy of measurement is at least comparable with that of any of the standard forms of weirs.

(2) The loss of head is relatively small and, varying with degree of submergence, becomes approximately one-fourth the loss of head for a standard weir.

(3) It will withstand a high degree of submergence without affecting the rate of free flow discharge.

(4) Unlike the weir, it is little affected by condition or velocity of approach.

(5) Unlike the weir, it is self-scouring, and operates without trouble in waters carrying large amounts of sand or grit.

(6) It is not easily altered in dimensions for wilful erroneous measurements.

(7) It has all plane surfaces and is easily constructed in most channels.

One-Half of a Parshall (10-Ft.) Flume, Looking Down Stream to Throat Section, Providence, R. I.

Indicating, Integrator and Recording Flow Instrument, Actuated by Parshall Flume, Providence, R. I.

(8) Operation is simple because it has no adjustable or moving parts.

(9) For most installations, the measurement of but one head (the inlet) is necessary.

Collaborating with other experiments, Ralph L. Parshall, Senior Irrigation Engineer of the Bureau of Agricultural Engineering, U. S. Dept. of Agriculture, after making literally thousands of calibrations at the Fort Collins, Colo., Experiment Station, devised the Venturi flume as it is known today, calling it "The Improved Venturi Flume."[1] The American Society of Civil Engineers in 1930 officially changed its name to "The Parshall Flume" in honor of its originator. It was originally developed for use in connection with irrigation, and has since found wide application in the central-west and western irrigation districts.

The Parshall Venturi flume has been applied to the measurement of sewage flows at the Providence, R. I., Sewage Treatment Plant, where a flume with a ten-foot wide throat is being used to measure flows varying from 5 to 120 million gallons per day.[3] At the Walden, N. Y., Sewage Treatment Plant a flume with a 9-inch wide throat is being used to measure flows varying from 5,000 to 1,200,000 gallons per day.[4] At Newark, N. Y., a flume with a 12-inch wide throat is being used to measure all the sewage passed through the sewage treatment plant.[5] Some years ago the writer incorporated a Venturi flume with a 6-inch wide throat into the design of a 1 m.g.d. sewage treatment plant for Maple Shade, N. J., where the available head through the plant was very limited.

Applications

The Parshall flume is particularly advantageous in measuring sewage where the available head is limited, and a nearly flat

*From WATER WORKS AND SEWERAGE, July, 1936.

TABLE 1—LOSS OF HEAD FOR GIVEN DISCHARGES, THROUGH PARSHALL FLUMES AND VARIOUS TYPES OF WEIRS

Discharge Sec. Ft.	Parshall Flume* 6-In Throat, Ft.	1-Ft. Throat, Ft.	2-Ft. Throat, Ft.	4-Ft. Throat, Ft.	Standard Rectangular Weir— 6-In. Crest, Ft.	1-Ft. Crest, Ft.	2-Ft. Crest, Ft.	4-Ft. Crest, Ft.	Standard Cipolletti Weir— 6-In. Crest, Ft.	1-Ft. Crest, Ft.	2-Ft. Crest, Ft.	4-Ft. Crest, Ft.	90 Triangular Notch Weir, Ft.
0.10	0.03	...	...	...	0.15	...	...	...	0.15	...	...	...	0.27
0.50	0.11	...	...	...	0.46	0.29	0.18	...	0.43	0.28	0.18	...	0.52
1.00	0.18	0.13	...	...	0.74	0.46	0.29	0.18	0.64	0.44	0.28	0.18	0.69
2.00	0.31	0.21	0.15	...	1.16	0.75	0.46	0.29	0.96	0.69	0.45	0.28	0.92
3.00	...	0.27	0.18	...	...	0.99	0.61	0.38	...	0.88	0.58	0.37	1.08
5.00	...	0.39	0.24	0.13	...	...	0.86	0.53	...	...	0.82	0.52	1.32
7.50	...	0.50	0.31	0.20	...	...	1.13	0.70	...	...	1.06	0.68	...
10.00	...	0.60	0.39	0.25	...	...	...	0.85	...	...	1.27	0.83	...

*70% submergence.

hydrulic gradient is mandatory. Table I illustrates comparative losses of heads for free-flow through Venturi flumes and over various standard types of weirs.

TABLE 2—STANDARD DIMENSIONS AND CAPACITIES OF PARSHALL'S FLUME

(Letters refer to Figure 1)

Throat Width W	A	⅔ A	B	C	D	E	F	G
	Dimensions in Feet and Inches							
Ft.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft.	Ft.	In.
0.5	2 1¼	1 4⅞	2	1 3½	1 3½	1	2	4½
1.0	4 6	3	4 4⅞	2	2 9¼	2	3	9
2.0	5	3 4	4 10⅞	3	3 11½	2	3	9
3.0	5 6	3 8	5 4¾	4	5 1⅞	2	3	9
4.0	6	4	5 10⅝	5	6 4¼	2	3	9
5.0	6 6	4 4	6 4½	6	7 6⅝	2	3	9

As stated above, the accuracy of the Parshall-Venturi flume is comparable with that of the standard weirs, and it can be used for any purpose which the standard weirs serve. Its principal applications may be listed as follows:

(1) To measure the entire flow through a plant or pumping station.

†(2) To proportion the flow through units operating in parallel.

†(3) To serve as a control for the automatic dosage of chlorine and other chemicals in proportion to the flow of sewage.

†(4) To measure and control the amount of return sludge in an activated sludge plant.

(5) In a sewerage district, to measure the sewage flows contributed by the various member municipalities.

Principle of the Parshall Flume

By examining Figure 1, it will be seen that the flume converges to its narrow or throat section. As the water approaches the throat, the velocity is constantly increased. It is still further increased after passing over the "crest," which is the junction of the level upper floor and the throat door at E. With the momentum thus acquired, the water is carried upward over the sloping floor of the diverging section and on through the flume. This unrestricted condition of flow is called "free flow."

If the grade of the channel downstream from the flume is reduced, the water, after passing through the flume, is resisted and checked in velocity, causing a backing up into the diverging section. If the water is backed up sufficiently to cause the surface

†The Parshall Flume, of itself, naturally can not perform duties 2, 3 and 4 unless the accessory-mechanical equipment, similar to that employed with Venturi Tubes, is provided.

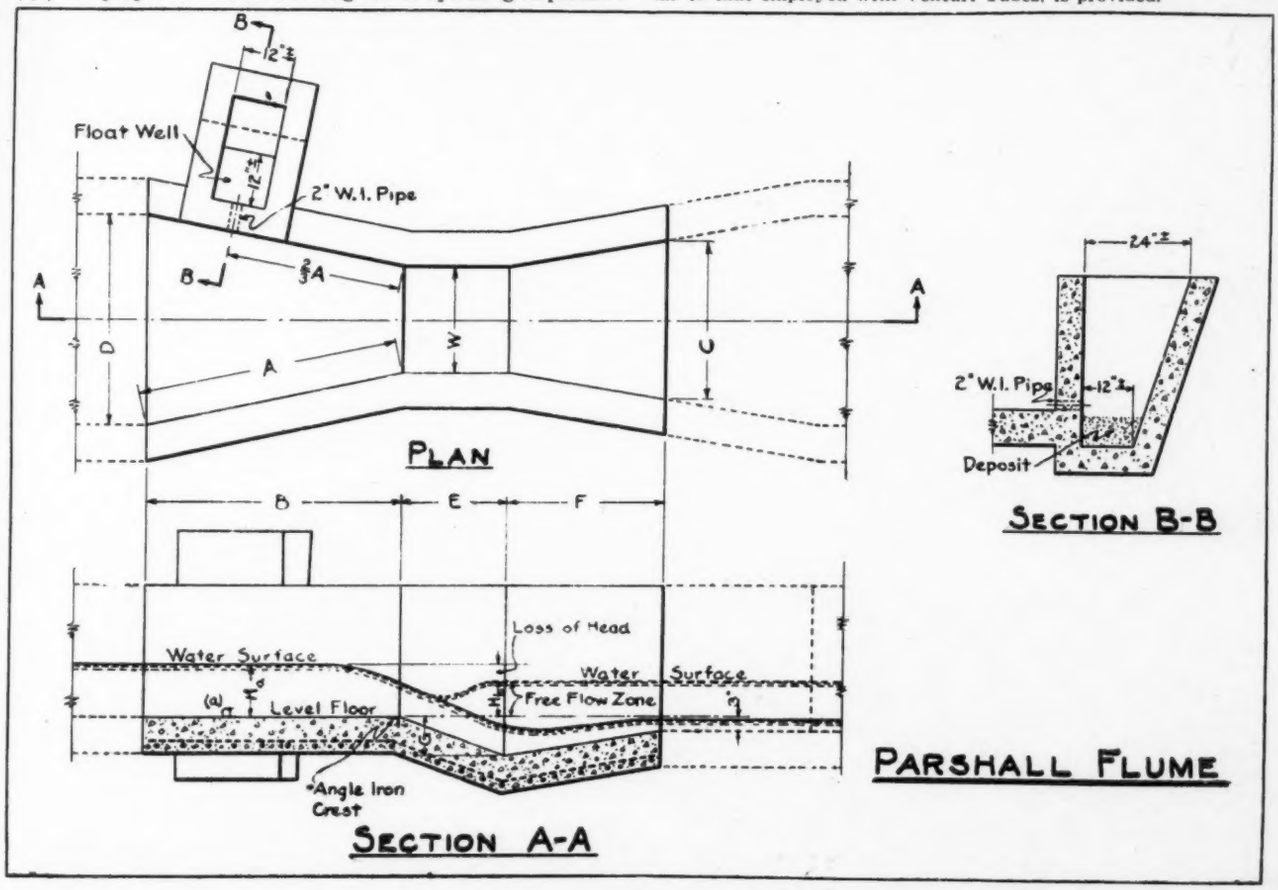
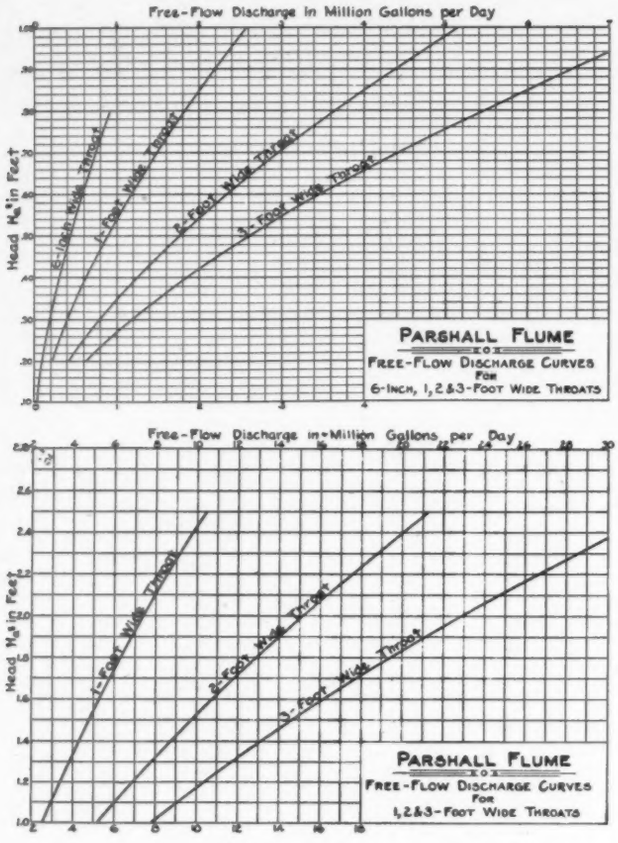


Fig. 1—Parshall Flume in Plan and Section


Free-Flow Discharge in Million Gallons per Day
Head Ha in Feet
6-Inch Wide Throat
1-Foot Wide Throat
2-Foot Wide Throat
3-Foot Wide Throat
PARSHALL FLUME
FREE-FLOW DISCHARGE CURVES FOR 6-INCH, 1, 2 & 3-FOOT WIDE THROATS
Free-Flow Discharge in Million Gallons per Day
Head Ha in Feet
1-Foot Wide Throat
2-Foot Wide Throat
3-Foot Wide Throat
PARSHALL FLUME
FREE-FLOW DISCHARGE CURVES FOR 1, 2 & 3-FOOT WIDE THROATS

Figs 2a and 2b—Discharge Curve of Parshall Flume

elevation of the water in the diverging section to attain the same level as that of the crest, a condition of zero submergence is said to exist. Still further backing up of the water will cause the elevation of the water surface in the diverging section to rise, producing what is called a hydraulic jump. Under such conditions, the flow is said to be submerged, the percentage of submergence being the ratio of the throat head (H_b) to the upper head (H_a), both being measured from the crest as a datum. The discharge of the flume is not reduced by moderate percentages of submergence, and is considered as having the characteristics of free-flow below the critical percentages. The 6-inch flume has free-low characteristics up to 50 per cent submergence, and the 1-foot, 2-foot and 3-foot flumes up to 70 per cent submergence. For ordinary installations, Parshall flumes should be installed with freeflow conditions.

Free-Flow Formula: For free-flow characteristics, as stated above, only the gage reading (H_a) at (a) need be measured.

For the 6-inch flume, the formula for free-flow discharge is:

$$Q_1 = 2.06\ H_a^{1.58}$$

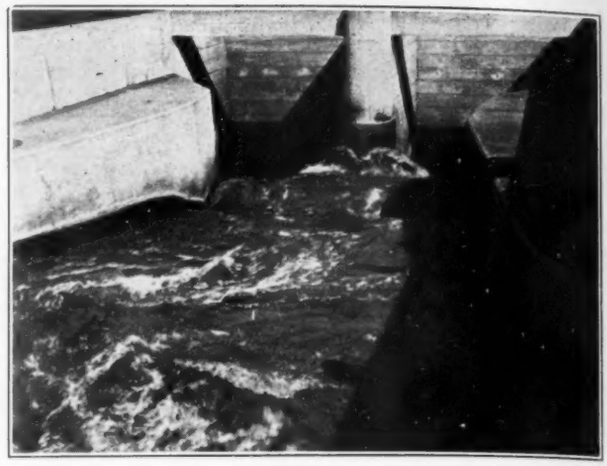
or $$Q_2 = 1.331\ H_a^{1.58}$$

For 1 foot to 10-foot flumes, the formula for free-flow discharge is:

$$Q_1 = 4\ W\ H_a^{1.522W^{0.026}}$$

or $$Q_2 = 2.585\ W\ H_a^{1.522W^{0.026}}$$

where Q_1 = Quantity of flow in second-feet.
Q_2 = Quantity of flow in million gallons per day.
W = Width of throat in feet.
H_a = Upper head in feet.



A 10-Ft. Parshall Flume in Service. The Hydraulic Jump Just Downstream of the Throat Is Plainly Visible

Figs. 2a and 2b are convenient charts for obtaining free-flow discharges for small and medium size plant needs. While experiments have shown the reliability and accuracy of the 6-inch flume above an H_a value of .80 feet, it is advisable to use a larger flume for flows in excess of 1 m.g.d.

Construction: By referring again to Figure 1, it will be seen that the flume has only plane surfaces. It may be constructed of concrete, or if for temporary use, of dressed cypress or white pine properly braced across the top. Two-inch lumber is recommended for the bottom and sides of the timber flume, with 4 by 4-inch sills and posts. If constructed of concrete, the crest should be formed by casting a medium size angle iron in the floor, as shown in Figure 1.

Measuring Sewage Flow: The measuring or recording device may be any of the home-made or commercial types of apparatus ordinarily used for this purpose. It may be an indicating staff gage, a graphic recording float gage mounted over the float-well. Or, in larger permanent installations, an indicating, recording and integrating instrument may be located at a point not far removed from the flume. The readings can be electrically transmitted to distant points such as has been successfully done at the Providence, R. I., Sewage Treatment Works.

Summary:

1. The Parshall flume is adaptable to the measurement of sewage flows.
2. It particularly meets low-head requirements.
3. It is simple and easy to construct.
4. Its maintenance requirements are negligible.
5. It can be connected with any of the conventional measuring and recording instruments.

Acknowledgment: To Mr. Ralph L. Parshall and the Colorado Experiment Station, the author wishes to express his appreciation for their kind permission to make use of much of the data which appeared in bulletins dealing with the Parshall (Venturi) flume.

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PRACTICAL ELECTRICITY IN THE PLANT

The A. B. C.'s of Electricity for the Water and Sewage Works Man

By MARSDEN C. SMITH

Engineer Water and Electricity, Department Public Utilities, Richmond, Va.

Taken from a series of short articles by Mr. Smith, dealing with the A.B.C.'s of practical electricity for water works and sewage plant operators.*

The author, a graduate electrical engineer, is a well known water works operator. He is, thereby, peculiarly well qualified to present these discussions, which should be of considerable benefit to operators and designers less thoroughly grounded in electrical matters.

If there are points in his contributions not clear to the reader, Mr. Smith offers to answer inquiries.

THE increasing use of electricity in water and sewage treatment plants produces problems of design, operation and maintenance with which the engineer in charge is generally but little familiar. Fortunately, while advanced electrical engineering is a very involved subject, a helpful and useful knowledge of its fundamental principles can be obtained quite readily by the trained personnel of such plant. To that limited end the presentation of this series of articles* is confined.

The Author

PART I—ELECTRICAL UNITS

The Volt

One of the most important units of electricity is the Volt. It is the unit of electrical *pressure*. Just as we measure water force or pressure in units of pounds per square inch or feet of head, the unit of electromotive (electric moving) force is the volt. In equations, its symbol is E. Voltage is sometimes expressed in print as the emf—abbreviation for electric-motive force.

Standard voltages are 110, 220, 440, 2,200, 4,000, and 13,200. The individual for whom these articles are intended is rarely concerned with voltages in excess of 2,200. Furthermore, the 110 volt standard is now in the process of change, and seems to be quite generally replaced by a standard of 120 volts.

Extra-heavy fittings and greater precautions are necessary with greater water pressures; so too, must greater care be taken both of life and property when higher electrical pressures are used. However, pressures of as little as 110 volts, in common domestic use, may prove fatal and care should always be taken to avoid personal contact with even these relatively low pressure circuits.

Most electrical apparatus is designed to operate at one of the above mentioned standard voltages. The use of other than these standards is both unnecessary and uneconomical. Incandescent lamps are generally rated at from 110 to 125 volts in five-volt increments. They may be obtained designed for 220 volts, but such lamps are not recommended except where no 110-volt service is available. Even then safety and economy demand the use of 110-volt lamps if possible.

Some Practical Considerations

Lamps are very sensitive to voltage change; and the operator should see that the lamps are purchased for the circuits on which they are to be used. For example, if the average voltage at the station is known to be 118 volts, 120-volt lamps should be used. Here the use of 110-volt lamps would increase the lamp replacement cost by almost 300 per cent.

Motors are not nearly so sensitive to voltage change as are lamps and will operate successfully at applied voltages within 10 per cent above or below normal rated voltage. Greater voltage variation will generally cause excessive heating and unsuccessful operation.

Small motors (less than 5 horse-power) are usually single phase and operate at standard lamp voltages. Large motors, 5 to 50 H.P., are cheaper when designed for 220 or 440 volts. Larger than 50 H.P. should be designed for 2,200 volts. Of course, local conditions may change these recommendations. One large plant has motors from 3 to 300 H.P. The station designers used 2,200 to 440-volt transformers; motors between 50 to 300 H.P. were ordered for 440 volts. A second set of transformers reduced the 440 volts to 220 volts for the smaller motors (up to 50 H.P.). Certainly this is unfortunate, because the larger and more expensive motors would have been of less first cost if designed for 2,200 volts, and the 2 to 5 per cent transformer losses, which materially increases operating costs, would have been saved. The smaller motors could all have been 440-volt type, thus here again would have been saved the second transformer losses. Here we see an evident error that a better understanding of the problem of electricity in design would have avoided.

Other than electrical engineers often fear the use of 2,200 volts. It is true, that there is no need for this higher potential, unless the size and number of motors justifies its use. However, where the total of as much as two or three hundred horse-power is required for motors larger than 50 H.P., the higher potentials are certainly advisable.

The relative advantage of the use of 220 or 440 volts as the operating voltage for the smaller motors is not so definite. However, for larger plants 440 volts seems more desirable. Safety requires the same care with 220 volts as with 440 volts, and a much wider range of motor sizes can be more economically operated at this than at 220 volts.

The Ampere

The second important unit of electricity to be considered is the Ampere.

It is the unit of electrical *rate of flow*. We are familiar with the various measures of the rate of flow of liquids; gallons per minute, etc.; so we should think of the unit rate of flow of electricity as the ampere. In equations its symbol is generally (I). In print Amperes are sometimes abbreviated to "Amp." Larger pipes are required to carry larger rates of flow of water economically; so too, larger wires are needed to carry larger currents (amperes) economically. Small pipes may be uneconomical because friction causes too great loss of water pressure. In exactly the same way, wires may be too small for the amperage (current flow) and cause an uneconomical loss of electrical pressure (voltage drop).

There are no standard currents as in the case for the voltage rating of electrical apparatus. Each appliance, lamps, heating devices, etc., takes from the circuit a current dependent upon its design and lack of resistance to flow. Motors require, for example, a current that varies with the load. All electrical apparatus (except lamps) should have its normal current rating stamped upon its nameplate. Lamp current is determined by dividing its watt rating by its rated voltage.

However, there are certain appliances such as wire, fuses and switches that are rated in terms of the current they may safely carry; thus currents are to this extent standardized. The plant manager should realize that these current ratings are fixed by the National Electric Code, and he should not permit greater current to flow through accessories than the limits established by this code. Oftentimes circuits are fused far beyond the rated capacity of the wire, which is supposedly being protected by the fuse. Such practice is both uneconomical and dangerous.

Most appliances, including motors, are connected between the supply lines, that is, in parallel. In this way the circuit voltage is impressed upon each appliance, causing a current to flow through the appliance of a quantity dependent upon its rating and load. These increments of current are added, hence the supply wires carry greater and greater total current as we work back toward the source of power. For example: Five 1,000-watt

*From WATER WORKS AND SEWERAGE, issues of October and December, 1936; February and April, 1937.

lamps rated 100 volts each require 10 amperes. Let us designate these as numbers one to five, from that nearest the supply to the most remote. Both wires between the supply and the first (No. 1) lamp carry 50 amperes; between 1 and 2, 40 amperes, and so on until between 4 and 5 the current has reduced to 10 amperes, or that required by No. 5—the last lamp. They all have (practically) the same voltages as the supply applied to their terminals.

Some Practical Considerations

When installing new apparatus there are two considerations of great importance: (1) Use wire of ample conductor size. (2) Employ insulation having a large factor of safety. For low potential circuits (less than 600 volts) 30 per cent pure rubber insulation will generally prove more economical than the standard code insulation. Particularly is this true in water and sewage treatment plants due to the prevalence of dampness in such locations. For 2,200-volt circuits rubber insulated cable is more easily installed than is varnished cambric cables. Rubber depreciates must more rapidly when subjected to heat and grease or oil than does varnished cambric, but it is less affected by moisture. For this reason, varnished cambric is never used without some form of outer coating, usually lead. Modern synthetic resins and other compounds are rapidly proving their value for use as the outer protective coating, materially lessening the installation difficulties. These coatings are deserving of consideration.

In general, where expert electrical maintenance is not available, the proper thickness of 30 per cent pure-rubber insulation, on conductors of adequate size for the current they will ever have to carry, will certainly well repay the increased investment cost. Where such expert maintenance is available, varnished cambric insulation may prove better for 2,200-volt circuits.

The Ohm

The unit of electrical resistance is the Ohm. In equations its symbol is (R).

If we close the spigot, even though there be water pressure at the valve, no water can flow because the resistance is too great. The same result is obtained when opening an electric switch; the pressure (voltage) still exists but the resistance (ohms) become so great that no current (amperes) can flow. This is an example of localized resistance.

Electrical resistance may be distributed, in fact *is* distributed along the conductor just as is the pipe resistance to water flow proportional to its size, length and condition. Fortunately, in electrical circuits the loss of voltage (pressure) is always directly proportional to the resistance and rate of current flow. Therefore, the loss of power (to be discussed in the next article) is proportional to the resistance and the square of the rate of flow or current.

An electrical device, such as a lamp, does not use or destroy current in the sense that an oil lamp consumes oil, but by its relatively high resistance limits the current that may flow as a result of the impressed electromotive force—voltage. Thus we have the simple but important equation known as Ohm's Law:

$$E = RI \quad \ldots\ldots (1)$$

There are no standards of resistance; however, the established resistance per unit length of electrical conductors and resistance alloys may be found in any electrical engineer's handbook.

Direct vs. Alternating Current

Formula (1) applies to circuits that contain resistance only, or in which the frequency is zero, as in the case of direct current. This term frequency must now be understood. If the polarity between two wires (A and B) of a circuit is not changed, the current flow will always be in one direction in the wires, thus constituting what is termed direct-current—(D.C.). If we alternate wires A and B from one side of the source to the other, once each ½ second, the direction of current flow in A and B will reverse once every ½ second, and will begin to flow in the original or *same* direction in a given conductor once every second. Electrically we would say that there was being produced "An electromotive force (current) having a frequency of one cycle per second." Fundamentally that is the difference between alternating and direct currents. Modern alternating currents closely follow the sine law in their time-potential value: and the standard frequency in this country is now sixty cycles per second.

When direct current is applied to a coil of copper or other wire (having resistance R) wound around iron, if the current and voltage be carefully measured, equation 1 will be found to apply. When an alternating voltage is applied this equation no longer can be used. This is because any magnetic circuit is an inductive circuit, and the effect of an inductance is to divide the alternating current into two components which are at right angles to one another. Hence to obtain the same current through the coil when an alternating voltage is applied, a greater voltage is required than when a direct voltage is used. So for alternating current circuits equation 1 becomes:

$$E = ZI \quad \ldots\ldots (2)$$

in which Z is the impedance of the circuit.

Many devices, such as heating appliances and lamps have little or no inductance; hence may be used on either direct or alternating current circuits of the rated voltage; but inductive devices, such as transformers and motors, cannot be used on direct current circuits unless especially designed for the purpose.

Transformers

The engineer for whom these articles are intended rarely is concerned with the use of transformers; however, a brief discussion of them is advisable. The standard transformer consists of two stationary coils of wire insulated from one another and wound around a common iron core. A special class, the auto-transformer, commonly used for motor starters, has only one winding with connections to some desired turn between the two end turns.

Of the winding in the auto-transformers, the turns connected to the power supply is the primary; the secondary winding is connected to the load. The voltage change between the primary and secondary is in direct ratio to the number of turns used in the two windings; conversely, the current is in the inverse ratio to the number of turns. Hence a transformer may be used to increase voltage as readily as to reduce it—the so-called "step-down." Many deaths have resulted from opening the high voltage switch, assuming the transformer "dead," when in fact the 110-volt side was still energized thus producing normal high voltage in the primary.

Instrument transformers are especially designed to accurately reduce the potential or current, as the case may be, for metering and other purposes. Care should be taken to always connect the secondary terminals of current transformers together with wire (short-circuit them) if the secondary circuit must be disconnected for any purpose while the primary continues to carry current.

It is well to know that transformers, if kept cool enough, can safely carry much greater than rated loads. Cold winter weather and artificial ventilation around the tanks is effective, but hot locations and days are dangerous. Tank temperatures should never exceed 90 degrees C. Contamination of the oil by dirt or even traces of moisture must be avoided. In larger units the oil should be examined monthly by a competent inspector.

The Watt

Another very important unit of electricity is the Watt, which is the unit of electrical power. The more commonly used unit is the Kilowatt, which is one thousand watts. The symbol for the Watt is (W); for the Kilowatt (KW). The mechanical unit of power is horse-power; one horse-power (H.P.) is the equivalent of 746 watts or 0.746 kilowatts. Due to the fact that the efficiency of small motors is approximately 75 per cent, the input in kilowatts is, by coincidence, closely the same as the mechanical output in horse-power.

With direct current, electrical power is the product of the current (I) and the voltage (E). Thus we have:

$$P = EI \quad \ldots\ldots (3)$$

However, substituting for (E) from equation (1), wherein $E = RI$, we have:

$$P = RI^2 \quad \ldots\ldots (4)$$

Or similarly, substituting for (I) where $I = \frac{E}{R}$ in the same equation:

$$P = \frac{E^2}{R} \quad \ldots\ldots (5)$$

Now, it becomes evident that electrical power varies directly with both current and voltage, if resistance is not considered, but as the square of either (E or I) if the resistance is considered.

PART 2

POWER FACTOR; ITS SIGNIFICANCE

With alternating currents equation (3) becomes the more familiar form, and—

$$P = EI \cos \theta \quad \ldots\ldots (6)$$

In this equation the Cos θ is designated as the power-factor. If an alternating current circuit contains resistance only (no capacity or inductance) the angle θ becomes zero; hence, its

cosine, which is the power-factor becomes unity. Electrical installations in water and sewage treatment plants rarely contain sufficient capacity (condenser action) to be of any practical effect, hence we may omit further reference to "capacity" in these articles. Inductance, however, is of great importance, and in practical installations may reduce the power factor as much as 30 per cent.

The actual mathematical value of the power-factor of practical circuits is difficult to compute; however, it is well for the engineer to have some idea as to the values that may be expected. Incandescent lamps and heating devices, since they contain but little inductance, are virtually non-inductive; hence, their power-factor closely approaches unity. Motors and transformers vary through very wide limits. Of course, a transformer being highly inductive when delivering no load, its power-factor is quite near zero; but, at rated load the power-factor becomes quite nearly that of the circuit being supplied by the transformer. Small motors, up to 5 h.p., require power at not more than 60 per cent power-factor; particularly so when operating at light loads. Large induction motors, at full load, now may operate at as high as 94 per cent; and, synchronous motors, more fully discussed in coming articles, may be operated almost as desired.

The objection to low power-factors is that larger currents are required for the same power, thus increasing power losses in the whole electrical system. Furthermore, low power-factors cause much wider voltage variations than do greater loads with higher power-factors. For this reason many power companies offer reduced rates to those consumers whose apparatus constitutes a load having a favorable power-factor. This fact may be of value to many larger operators. It is true, however, that plant operators can exercise but limited control over the power-factor of their stations except through the selection and operation of the motors. This phase of the subject will be later discussed when motors and their characteristics are considered.

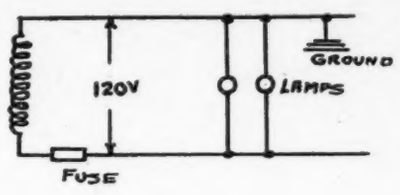


FIG 1

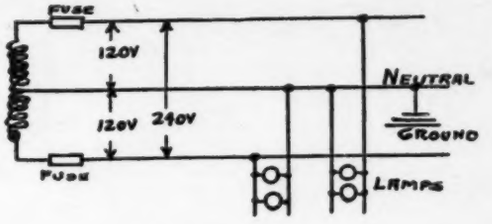


FIG 2

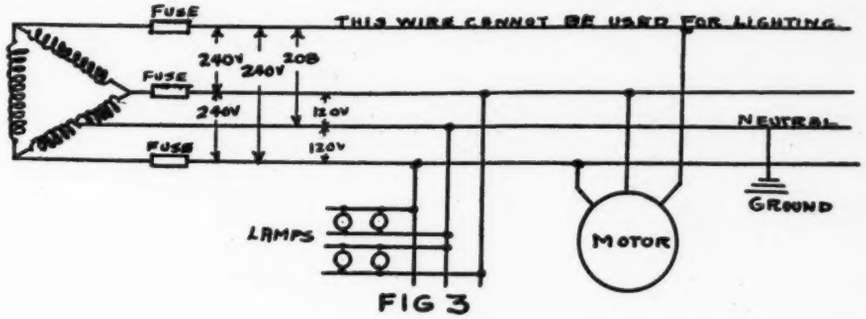


FIG 3

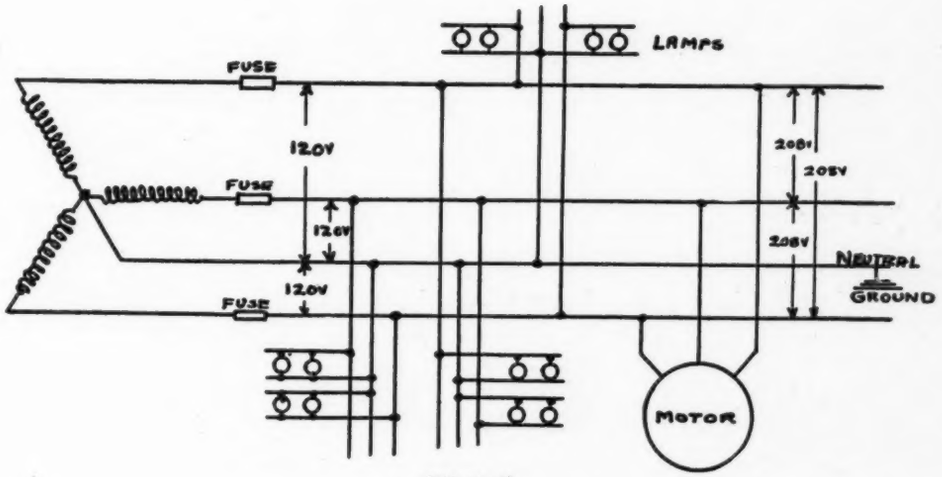


FIG 4

Circuits: *Figs.* 1, 2, 3 *and* 4

The Kilowatt-Hour

The kilowatt-hour (KwHr) is the unit by which electric power is generally sold. As its name implies, it is the average power consumed, in kilowatts, multiplied by the number of hours involved. For example: if an electric iron is operated for two hours at average rating of 600 watts, there is used $600 \times 2 = 1200$ watt-hours, or 1.2 KwHrs.

The volt-ampere (VA) is the product of the volts and amperes of a circuit or an appliance, without reference to power. Thus, the transformer is always rated in kilo-volt-amperes (KVA) because its parts can be designed for the voltage and current value desired, but the power-factor of its load may vary through wide limits. Thus we see that:

$$KW = KVA \times \text{Cos } \theta \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Hence, if we are to know the safe load for a transformer rated at 100 KVA, we must first determine the power-factor of the load to be connected. If we may assume the load to be one-half lamps and one-half small motors; we may approximate the average power-factor to be 82 per cent. Hence, by equation (7) we find Kw $= 100 \times 0.82$ (82 Kw) to be the safe load for this case.

The Cos θ, which we now recognize to be the power-factor, is actually the cosine of the angle of time-phase displacement between the current and the voltage of an alternating current circuit containing "capacity" or inductance.

Circuits

The term, "phase," is also applied to designate the circuits of an alternating current system. In the "Single-Phase" system the *voltages* are in the same time-phase in all parts of the system. In the "Two-Phase" system, the two voltages are 90 degrees apart. In the "Three-Phase" system they are 120 degrees apart.

In another sense, there are in effect one or two or three circuits in the single, the two or the three-phase systems. Of course, the power-factor may be different in each phase; hence the currents in the phases may not be of exactly the same angular difference as the voltages producing these currents.

The simplest circuit is that comprising the single-phase (two-wire) system, as in Fig. 1. This is used for the final branch circuit of larger systems, and in case of small loads, including most residences, it is always used.

The single-phase, three-wire system is next in capacity and in frequency of use. Single-phase, two-wire branches are connected thereto as shown in Fig. 2. The evident advantage of three wires over the two-wire system is that when loads are

balanced, the neutral carries no return current, hence the lamps and appliances operate at 120 volts, whereas the circuit operates at 240 volts. In this way twice as much power can be carried over the same wires, by merely adding one additional wire.

Grounding Practice

The neutral must be grounded. It should be the same size as the phase wires; and, it must *not* be fused or connected to any switch, and the wire used for the neutral must have white covering for identification, and the neutral must be connected to the white screw in all receptacles. In the single-phase, two-wire system one of the wires must be grounded and the same rules as given for the neutral conductor wire must be observed.

(Grounding practice as it affects water works piping will be given some discussion at a later point in this article.)

Three-Phase Standard for Heavy Duty

The three-phase (three-wire) system is standard for motor loads. If lighting is required, the neutral of one transformer (made larger to carry the additional load) is brought out as in Fig. 3. Most power companies limit the single-phase load that may thus be supplied to 50 KVA. In addition, this method of supplying the lighting loads makes service interruptions more frequent because of the necessity for grounding one of the transformer windings. Perhaps most serious of all is the objectionable flicker in the lights obtained when starting motors, particularly elevators connected to the system. Of course, economy often rules and hence this system is frequently used; but unless the motors are relatively small, and are started very infrequently; it is undoubtedly better to separate the lighting and very small motors from the power system.

The formula for power in the different systems, with balanced load, is given in the following table:

System	*Power*		*Max. Volts to Ground*
Single-Phase (Two-Wire)	$P = EI\cos\theta$	Here E=120	120
Single-Phase (Three-Wire)	$P = EI\cos\theta$	Here E=240	120
Two-Phase (Four-Wire)	$P = 2EI\cos\theta$	Here E=120	120
Three-Phase (Delta)	$P = \sqrt{3}EI\cos\theta$	Here E=240	207.8*
Three-Phase (Y)	$P = \sqrt{3}EI\cos\theta$	Here E=207.8	120

*Volts to ground on lighting circuits is 120.

The two-phase (four-wire) system is so little used that no discussion is necessary.

PART 3—CIRCUIT PROTECTION

Fuses and all electrical circuit-breakers are similar in function to the safety valve on a boiler; and hence they should be seriously considered. They are all intended to open the circuit, thus stopping the flow of current, should the current exceed a predetermined or dangerous rate through these safety devices.

While the problem of circuit protection becomes at times quite involved, still there is much that can here be discussed to advantage. In the first place, the Natinal Electric Code is now almost universally accepted as the authority for the safe utilization of electricity in all except central station systems. Consequently, the engineer should obtain a copy of this useful and important publication.

Fuses and Circuit Breakers

Fuses are the cheapest and simplest of all protective devices. They consist of a piece of relatively high resistance alloy wire or tape, designed to melt, and thereby part, at the current at which the fuse is rated. The wire is enclosed in a suitable flame-proof case to prevent ignition of surrounding materials at the time the fuse flashes and melts. The use of fuses is now confined almost entirely to circuits the importance of which does not justify the more expensive and accurate devices. The type now approved, known as the "refillable type," permits the renewal of the fuse link, using the expensive part (the cartridge) over and over again.

For those applications in which the replacement of fuses is frequently necessary, thermal relays or air circuit breakers are to be recommended. Motor circuits fall in this classification. Thermal relays and circuit breakers can permit a greater than rated current pass for a short time, as during the starting period of a motor, and therefore are of especial advantage for this service. The current capacity as well as the voltage ratings of this class of protective devices are limited, and when greater limits are needed the oil circuit breaker must be used.

The oil used in circuit breakers must be especially selected for this service; and no other oil should ever be used. This precaution is essential for the reason that the oil must have high insulation value, high flash point, low carbon content, and wide temperature viscosity constant—all in order to quickly quench the arc that is formed with each opening of the contacts.

Relays

The overload operation of an oil circuit breaker is usually actuated by an auxiliary device known as a relay. Relays may be of several types: the instantaneous, the inverse time limit, and others. The modern relays are truly marvelous devices; however, the types needed by the water works plants are, in the main:

(1) *The Instantaneous Type*—dash-potted relays with direct mechanical trip. Here a coil which carries all or a definite part of the load current raises a solenoid when the current flow exceeds a predetermined value. The rising solenoid mechanically releases a trigger, which in turn permits the oil circuit breaker to open. An oil-filled dash-pot retards the solenoid movement. The dash-pot opening is adjustable, hence the time for opening with a given over-current can be selected as desired. The oil in the dash-pot should be inspected at intervals and replaced if dirt or sludge has accumulated. While rather crude, this device is sufficiently accurate for the protection of most small motor circuits.

(2) *The Air Bellows Type*—This type is not much used now. An air bellows, with an adjustable escape valve, is substituted for the oil dash-pot described above.

(3) *The Induction Type*—This relay is more expensive than those above mentioned, but its use is justified in the protection of all important cicuits.

With the induction relay, when the current exceeds the desired value, the torque on an aluminum disc, mounted on the same shaft with the relay contacts, causing the shaft to rotate. Such rotation causes the opening (some cases the closing) of the relay contacts, which in turn electrically energize the main tripping coil on the circuit breaker. The advantage of this type is that the time of opening the main circuit breaker can be determined to a fraction of a second; also, that the limits of control are so wide that these relays, with suitable current transformers, become almost universally applicable and highly accurate protective devices.

To repeat, too much care cannot be given the subject of circuit protection. Over-fusing (use of fuses with too great capacity) of circuits is dangerous and uneconomical. Noting a too frequent operation of the overload, protection of any appliance warrants prompt investigation. The source of the trouble should be remedied by correction, rather than following the easiest path of using too large circuit protection to overcome an annoying operating circumstance.

Grounding—Its Essentiality

It is no exaggeration to say that without adequate grounding, satisfactory electrical service would be virtually unknown. In addition, safety would be a word more than a reality. Even so, many groundings are so deficient in quality as to become actually a hazard instead of a safety effect. Many persons have been swindled into paying for a false sense of security when installing lightning rods having many ornamental glass balls but no grounds. Thereby the victim is actually inviting the lightning to strike the house but offering no protection by way of a cable or rod to conduct the electric discharge into the earth and there dissipate it.

Grounds should be carefully made. Use not less than No. 2 B&S gauge copper wire. Several grounds are preferable to a single ground in order to lessen the chances of broken connections. Use the water pipe system; the larger the pipe, the better. Do not use the gas, gasoline or oil pipe lines. Be sure the connection between the wire and pipe is electrically and mechanically as perfect as possible. If no pipe system is available, drive at least three 1¼-inch pipe, or equivalent copper rods, *well below the moisture line* in the earth. A good test is that the driven ground connection, when shorted, should blow a 30-ampere fuse at 120 volts.

Much discussion has recently been raised in the water works field as to the effects of attaching the electric circuit "neutral" wires to the water pipes. There is no question that the damage done to water systems by stray direct currents, as from street railways, has been indeed enormous. Here we have electrolysis at its worst, and the destruction of the metallic pipes at spots where the current leaves the pipes is rapid. This condition is inexcusable and should be prohibited everywhere.

However, in the alternating current system the damage is not so evident, and many doubt its *real* existence—or at least its seriousness. Also it is quite possible that were all connections between electrical and water systems removed, electrical service as we know it today would be a thing of the past. And even should such action force the electric companies to seek other means of obtaining the necessary protection now provided by these ground-

ing attachments, the water systems would be subject to the same distress now *debatedly* suffered. It would seem certain that more severe difficulties would be caused by the same currents finding their way to the water system in a then uncontrolled routing and dissipation which present practices have been designed to effect.

The necessity for grounding the electric circuits is to prevent dangerous high-potential voltages (through mistakes or accidental contact) from increasing the normally low-potential circuits to a dangerous loading. The wiring for lighting systems of buildings is designed for a maximum of 150 volts to ground. Let us assume that a street series circuit operating at 5,000 volts should fall across the service wires from the pole to your home. With no ground on the "neutral" of your secondary wiring, its potential would be raised from its normal low value to a maximum of 5,000 volts. Certainly something must happen; either a fire is started, or perhaps a member of your family may be killed. The effect of such danger has been observed when service thawing current reaches the house wiring. In these instances the "ground" has worked in reverse, but proves its safety value and the necessity of "breaking" the service line before electrical thawing is started. Now consider these same conditions to exist, except that now your "neutral" is properly grounded. When the high-potential circuit is now temporarily crossed with service, the high-potential currents are safely carried to ground, and no one in the home would realize the possible disaster that the ground connections have avoided.

When, What and Why Ground?

There is no doubt that a full study and discussion of the entire subject of grounding by the new functioning joint committee will prove well worth while. It is certainly to be hoped that there will result a greater care in the preparation and arrangement of ground connections between the electric and water systems, and that the volume of curent flow be intelligently regulated. We, the water utility interests, should not embarrass this effort by hasty demands to prohibit all grounding of water systems. As a matter of fact, we could not do so, even if thoughtless enough to demand such.

[Water works men have themselves found difficulty in effectively grounding pumping station motor circuits by any other method than an efficient connection to their own pressure mains leaving the station.—Ed.]

No wires used in lighting systems should have more than 150 volts to ground. The wires of power circuits, such as 220 or 440 volts, *should not be grounded.* All appliances, frames of motors, conduit, etc., in addition to the "neutrals" of lighting systems, should be carefully and effectively grounded. Inspect grounds frequently. The snuffing out of a life may be the penalty if you do not. Satisfactory operation is another, if secondary, reason for so doing.

PART 4—MOTORS

Alternating current motors are of two general types: the synchronous and induction. The main difference between these two types is that, while the synchronous motor can run only at a definite constant speed (synchronous speed), the induction motor must operate at a speed dependent upon the load applied, but never at synchronous speed. There are other important differences that, to better advantage, will be mentioned later.

Synchronous Type

At a given frequency the speed of a synchronous motor may be determined by the equation;

$$N = \frac{120f}{P} \quad \ldots\ldots\ldots (8)$$

in which N = revolutions of rotor per minute (RPM); f = frequency in cycles per second; P = number of poles.

Since the standard frequency is 60 cycles per second, equation 8 is generally expressed in the form:

$$N = \frac{7200}{P} \quad \ldots\ldots\ldots (9)$$

From this it is evident that the maximum speed for a 60 cycle motor is 7200/2 or 3600 RPM, and the speed, N, from equations 8 or 9 is known as the synchronous speed of the motor. This, for 60 cycle motors, is the constant 7200 divided by the number of poles; and, since the number of poles must be an even number, synchronous speeds become 3600, 1800, 1200, 900....RPM. One of the greatest limitations of the synchronous motor is that it cannot be built to operate at other than synchronous speeds, when oftentimes an intermediate speed is needed.

On the other hand, the fact that it runs at an exact speed is quite frequently its greatest asset. Electric clocks and timing devices depend upon this characteristic for their value and dependability as to accuracy. Pump drives, and mechanical devices of all types that require an exact and fixed speed, necessitate the use of the synchronous motor for this reason.

Another marked difference between the synchronous and induction motor is that the former requires salient magnetic poles, excited (magnetized) from a source of direct current; whereas, the induction motor has no such poles and requires no separate excitation. In fact, the standard squirrel-cage motor is well named, because its rotor is essentially nothing more than a circle of bars parallel to the shaft which are held in place and short-circuited by two metallic rings. Picture the revolving cage for the squirrel's exercise and you have it—thus, the name.

Unfavorable Characteristics

The necessity for this auxiliary direct current is indeed unfortunate, because direct current generators are difficult to maintain. Hence, greater skill and maintenance are required for synchronous than for induction motor operation. Then, too, the starting characteristics of the synchronous motor are rarely satisfactory. The starting torque (that is, the twist or pull) cannot approach that of the induction motor; frequently necessitating expensive and complicated methods of holding the load off the motor until it has reached full speed. Fortunately, centrifugal pumps may frequently be started under no-load without inconvenience, which renders this deficiency of the synchronous motor of no real importance.

Favorable Characteristics

On the favorable side of the ledger, the synchronous motor does possess the ability to operate with a "leading" power factor, contrasted to the rather decidedly "lagging" power factor of the standard induction motor. As has been stated previously, many power companies offer a lower rate to consumers whose requirements make permissible a desirable power factor. Where this is the case, the ability of the synchronous motor to operate at the "leading" power factor may have influence in the selection of the type of motor to be adopted.

From the above, it can be seen why, for water works and sewage treatment plants, the use of synchronous motors is frequently advised against. They are only to be considered when exact speed is essential or power costs may be lowered appreciably by the favorable power factor. Even then, the engineer will do well to be certain that savings in power bills will offset the increased operating difficulties that are certain to be realized in the use of synchronous motors.

Induction Type

The induction motor differs from the synchronous type in that it requires no separate excitation, and its ability to operate at a variable speed, as contrasted to the constant speed synchronous motor.

At no load an induction motor will run almost up to its synchronous speed. It should be understood that while the induction motor has no salient poles, the stator is wound to produce two, four or any even number of poles, just as is the stator of a synchronous motor; hence it has a synchronous speed of 3600, 1800, 900 RPM, just as does the synchronous type.

As the load on an induction motor is increased, the speed gradually lessens until at full rated load the speed is reduced from two to four per cent of its synchronous speed. Thus a given motor may have a synchronous speed of 1200 RPM, a no load speed of 1199 RPM and a full load speed of only 1170 RPM. If the load is further increased, the "slip" (as the loss of speed is called) will increase until a definite value is reached, at which point the motor will come to a stop. This load is known as the "pull-out" load.

Favorable Characteristics

Standard induction motors have very favorable starting characteristics, requiring relatively a small starting current and producing 200 or more per cent of full load torque. They are the most rugged and reliable of all motors. But while they will successfully operate under most adverse conditions, reasonable care should be taken to keep the air ducts and windings free from lint and dirt. The oil in the bearings must be flushed and changed at least once each year.

Smaller and specially designed induction motors require no starting device, and may be started by applying normal full voltage. Larger motors require reduced voltage for starting, which is

usually obtained from auto-transformers, called starting compensators. Two coils, each on an iron core, are connected open-delta across the three-phase lines; a 40, 50 or 60 per cent tap is taken to the motors for starting. After the motor has started and reached a constant speed, the compensator is disconnected and full voltage goes to the motor.

Variable Speed Motors

The wound-rotor induction motor, for operating at variable speeds, is not so rugged as is the standard squirrel-cage type. It is more expensive and also usually less efficient. A misunderstanding of the speed characteristics of these motors has caused no end of trouble. We may gain a clear conception of the speed variation of the wound rotor, induction type motor if we think in terms of "slip." As stated above, the standard squirrel-cage motor "slip" varies from virtually nothing at no load to about 3 per cent at full load. With the wound rotor, external resistance may be added to the rotor circuit, the effort of which is to *increase* the slip. Hence, this motor will run at essentially *constant* speed at no load, regardless of the amount of external resistance introduced in the rotor circuit. But, as the load is applied, and the greater is the external resistance, the more rapidly will the speed drop off.

Practically, this means that if we desire to drive a centrifugal pump at a variable speed, in order to vary the head and quantity delivered, we must first learn from the pump manufacturer both the speed and the horse-power required by the pump for each value of head-quantity desired. This data is then furnished the manufacturer of the motor who will design the external rotor resistances so that the various controller positions will connect the correct resistance to cause the speed to be that needed for the pump to operate under the desired condition.

Since power is a product of speed and torque, it should be remembered that less horse-power output can be obtained from a motor operating at a reduced speed than at its normal full speed. The reduction in motor output is approximately proportional to the reduction in speed. This fact should be considered at the time of purchase in order to be certain that the motor will not be excessively heated when operating at any of the reduced speeds. The same resistors that serve for speed control are also used for starting, hence no compensator is required as is the case for some of the standard squirrel-cage types.

Motor Ratings

The rating of most electrical apparatus such as motors, transformers, etc., is based upon the temperature rise that will occur when the device is operated continuously under normal full load and normal voltage conditions. Many manufacturers recommend a limit of fifty-five degrees centigrade rise, while other base their estimates upon a rise of only forty degrees. After all, this simply means that with a given motor rated at 100 HP, at 40 degree rise would be rated at 125 HP at 55 degree rise. All things considered, it seems to be the consensus of opinion, and dictate of wisdom, that all important motors in water works and sewage treatment plants should be purchased for a guaranteed rise, not to exceed forty degrees centigrade.

RAPID EMERGENCY METHOD OF THAWING HYDRANTS*

By E. E. JACOBSON

Chief Engineer, Lexington Water Co., Lexington, Ky.

One of the many worries of the water works man during the cold winter months is the problem of fire hydrant maintenance and their operation when the thermometer drops below freezing.

Proper inspection and drainage of fire hydrants will eliminate most of the trouble but hydrants only a few days after inspection have been found to contain water in the barrel. As the weather turns cold the water in the barrel becomes ice and the hydrant will not operate. No doubt every water works superintendent in states that have cold winters has experienced frozen fire hydrants.

The method used in Lexington, Ky., for a number of years as an emergency method of thawing ice from hydrant barrels is by pouring concentrated sulphuric acid into the hydrant barrel. During the Fall each piece of apparatus of the Lexington Fire Department is supplied with a quart bottle of sulphuric acid (66% commercial). When the acid is used the Lexington Water Company is notified and another bottle is sent to the fire station. In the Spring of the year these bottles are collected and fresh acid is issued each Fall.

When answering an alarm and a hydrant is found to be frozen, the acid is poured into the barrel through the nozzle and a slight pressure put on the stem operating wrench. As soon as the heat produced by the acid drills a hole through the ice cake the hydrant is opened, flushing out the acid with the first gush of water.

In frozen hydrants we have found that the ice forms first above the valve and in most cases it is doubtful if the acid reaches the valve because the stem turns and the water is turned on as soon as the ice melts around the stem.

The average time for thawing hydrants with acid is about three minutes although this would depend upon the thickness of ice in the barrel of the hydrant, and might vary considerably from the above time if very thick.

The advantages from this method of thawing hydrants comprise the ease of handling the thawing material on the fire trucks, the small space necessary on the trucks, simple to use, inexpensive, and the rapidity of results. Hydrants in which acid was used have been taken apart and no ill effects to the hydrant parts could be found.

The effectiveness in the use of sulphuric acid for this purpose can be determined by the following letter from the Chief of the Lexington Fire Department:

Mr. E. E. Jacobson, Chief Engineer — April 11, 1936.
Lexington Water Company,
Lexington, Kentucky.

Dear Mr. Jacobson:

Relative to our conversation this morning, I am furnishing you with all the information that I have in regards to the use of sulphuric acid in thawing fire hydrants during extreme cold weather.

In case a hydrant is found to be frozen, one of the caps of the hydrant is removed and a quart of acid is dumped into the barrel of the hydrant. The suction hose is then replaced on the hydrant, and in the majority of the cases the hydrant is thawed out by the time the suction is replaced, and the hydrant is turned on. The water and acid is allowed to flush out through the pumper or the hose, and we have found that little or no damage is caused by this action, due to the fact that the acid is neutralized by water to such a degree that it is harmless to the pumper or the hose.

In some instances the acid is a little slow about thawing the hydrant, but in these cases it is usually in certain parts of the city, where the surface water seeps in the barrel of the hydrant, causing the hydrant to have more water than usual in the barrel, but as soon as these hydrants are found, your company has had them filled with alcohol, thereby eliminating this trouble.

You will notice that we say that we replace the suction or the hose to the hydrant before we turn on the water. This is done to prevent acid burns to members of the department and the hose and apparatus that is near the hydrant. The first spurt of acid and water from the hydrant would be dangerous to any thing that it touched, but by replacing the cap, the acid is diluted with the water to a point where it is practically harmless to any thing it might touch.

It has required from two to eight minutes to thaw a hydrant with acid, where it usually requires about ten minutes to thaw out a hydrant with a regular thawing device, old style thawing device.

A test was made at fire department headquarters today. A fifty pound block of ice was used and one quart of sulphuric acid was poured into a hole in the ice. Ten minutes later a hole was burned in the ice eight inches deep, six inches wide and ten inches long. Of course, this was a little longer than it would have been in a hydrant, due to the fact that acid will follow the stem of the hydrant and penetrate into the ice faster than it did during the test. We have found the use of sulphuric acid for thawing hydrants to be most satisfactory.

C. J. HENRY,
Chief, Lexington Fire Department.

*From WATER WORKS AND SEWERAGE, December, 1936.

THAWING FROZEN SERVICE PIPES

By REEVES J. NEWSOM

President, Community Water Service Co., New York, N. Y.

The most rapid and economical method of thawing has been by the use of electric current. The most commonly used scheme of electrical thawing has been to get the local power company to mount transformers on trucks and to connect to existing power lines in the streets. The cost of this method is apt to be greater than the use of other types of electrical equipment, but there is usually not time to get other equipment after the freeze-ups began. In outlying districts no power lines were available in some cases, and other methods had to be resorted to. Engine driven generator sets especially designed for the purpose were only occasionally available, but the modern electric welding outfit was found to have approximately the voltage and amperage range required for thawing services, and where these outfits were used for thawing mains two of them were generally used in parallel.

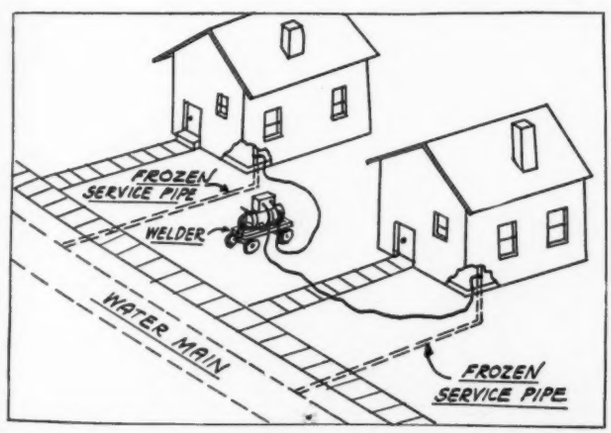
A third type of electrical equipment which was effective for short services, where connections could be made close together, was a small portable transformer with a capacity of about 150 amperes at 20 volts. On some systems a surprising number of services were successfully thawed with equipment of this type—the current being taken through the residence wiring outlets.

Where only a few frozen services were encountered or where the electricity was not available; or, where it was ineffective due to rubber gasketed couplings, new lead substitute joints in the intervening main pipe, or lack of capacity to thaw copper services, steam and hot water were used. One man can operate the steam outfits and do the thawing.

Steam is effectively used by generating it in a small portable boiler and feeding it under about 10 lbs. pressure through a ⅛-inch copper tube or 3/16-inch block-tin tubing. It is successful for only relatively short straight pipes where the steam jet can be advanced against the ice face as it melts. Where sharp bends are encountered and the tube cannot be advanced, the steam will not carry forward through the melted ice. Also, if the length of the service is too great the steam condenses in the tube before reaching the ice face and is not effective.

Hot water is, in general, more satisfactory than steam, though it requires two men to operate the equipment—one to push the tube into the pipe as the melting of the ice advances, and the other to operate the small force pump required. This method can be used on a longer service than the steam process and the hot water will carry farther beyond the end of the tubing when it meets an obstruction than does steam.

Small sections of 4-inch main about 75 ft. in length can be thawed by this method and if ⅜-inch iron pipe is substituted for the copper or tin tubing, the length that can be thawed can be approximately doubled. Where relatively new lead-substitute (compound) joints are encountered, preventing the use of electrical thawing, this becomes a valuable method of thawing larger mains also.



Sketch showing electric thawing equipment hook-up to thaw two services. One connection may be made to a fire plug, if convenient, when only one service is to be thawed. Before turning through the current the house piping is disconnected from the service line for safety.

Mobile Welding Generator Set Thawing Frozen Service Lines.

Time Required for Thawing

Experiences indicate that the time required for thawing services by all three methods varied through a wide range. Where equipment of adequate capacity was available for electrical thawing services were often thawed in from three to ten minutes and small mains in from one-half to two hours. Both hot water and steam thawing require a considerably longer time than this. However, in many instances, because of lack of experience and precedent, many jobs of thawing of both long services and mains were attempted without adequate equipment; and, as a result, two or three hours were often spent on a service and as long as ten or more hours on a main.

Cost of Thawing Operations

The cost of electric thawing was made up of many combinations of charges. In cases where hook-ups were arranged with the local power company, the charge was sometimes a stated amount per service or an hourly charge for the equipment, with or without a current charge. Welding outfits were supplied both on a per service basis and an hourly charge for men and equipment. The cost commonly varied between $2.50 and $7.50 per service for electric thawing, and the use of hot water and steam applications also came within this range. A common charge for welding outfits was $4.00 per hour, although it varied from $2.50 to $7.50 per hour.

Difficulties Encountered

One of the principal difficulties encountered in thawing by electricity has been the occasional inability to get a closed circuit through the pipe or main that will carry sufficient current to produce the required heat. The most common cause of this type of trouble is the presence of lead substitute joints in the section of main between the frozen service and whatever point is used for the circuit making connection. The weight of evidence from past experience appears to show that new lead substitute joints definitely will not carry sufficient current for thawing. Depending somewhat upon the character of the water, joints of this type in about five years will have formed, by corrosion of the iron in the bell and the material itself, a contact that will carry the current. This contact is somewhat fragile, however, and if too large an amperage is forced through it, it may burn through and break the circuit or create arcing and damage, after which other means than electricity will have to be used. To avoid this, it is necessary to keep the amperage below 200, or probably 150, and keep the current on for the extra time required. Rubber bushed repair couplings or joints are another reason for being unable to get a closed electric circuit, and, except in rare instances, time does not seem to produce a satisfactory current

One of the Mobile Welding and Thawing Units—Ottawa, Canada, Water Department.

carrying contact unless much higher voltage is available than is needed for ordinary thawing work.

Failure to ascertain that there is no other path for the current to take than through the service line may lead to failure in thawing, even though the ammeter indicates that the proper amount of current is flowing. In some cases the current has taken a path through the house wiring and has heated the small wires (and BX cable carrying them) hot enough to set the house afire. It is not sufficient merely to detach the ground wire that is customarily found near the cellar wall, because other ground connections may be present elsewhere. *A complete disconnection of the piping system from the service line, by removal of a fitting or the meter, is the only safe course.*

Necessary Consideration in Successful Thawing

The thawing of services and mains by the use of electric current will be more uniformly successful if water works operators will bear in mind the fundamental characteristics of current flow and energy transference. Amperage is the measure of quantity of current flowing and is the most important element to consider because on the one hand the heating effect desired is principally dependent upon the flow of a sufficient number of amperes of current and, on the other hand, damage to joints and pipe is caused by too great an amperage. Voltage is the measure of electric pressure which is driving the current through the pipe. Voltage is therefore important only because of the amperage which it will force through the resistance of the pipe and joints. Ohms are a measure of resistance—i.e.—electric friction. The relation between the three is expressed as Voltage equals Amperage times Ohms. Thus, the greater the resistance, the greater must be the electric pressure (voltage) to force through a given amount of current.

Resistance, therefore, if it be in the joints, is a detriment to current flow and to the thawing. But the resistance of the material of the pipe to be thawed is useful in thawing, for ultimately it is the heat, produced by the force of the current, that melts the ice, and the greater the resistance, the greater the heat produced by a given amount of current forced through.

The transference of electric energy into heat in a conductor takes place according to a law first stated by James Joule, an English physicist. According to this law, the heat produced is directly proportional to the resistance of the conductor, the square of the amount of current and time the current is flowing. Thus it will be seen that a material which is a poor conductor and offers greater resistance to current flow will get hotter than one which is a good conductor. Also, a relatively small increase in amperage will greatly increase the heat produced as the variation is as the square of the amperage increment.

It would appear from this law that any difficult job of thawing could be done by merely continuing the current flow for a long period, and to a limited extent this is true, but it must be remembered that the heat produced in the pipe is immediately dissipated by the ice inside and the cold soil on the outside. Therefore, for any rate of heat production there is a point reached where it is dissipated as fast as produced; and, if in a reasonable time the pipe line is not thawad it is safe to conclude that too much of the heat is being lost through the soil and mere continuance of this condition for a longer time will not bring success. More heat must be provided and since the resistance of the pipe cannot be controlled, increased current flow (amperage) is needed. To secure this additional flow of amperes an increase in the electrical pressure (voltage) is necessary.

As a result of this law of Joule's, it can be seen that a copper pipe, being a good conductor, can only be heated by passing a considerable amperage through it and for a longer time than in the case of other materials (such as iron) which are not such good conductors. Comparing the resistance of the various metals used for water pipes, in order, copper is the least resistant. Considering copper as 1, steel is 7, wrought iron is 9, lead is 12, and cast iron is 73. Since copper has 1/7th to 1/9th the resistance of steel and iron and 1/12th that of lead, it is necessary to put through at least twice the amperage for approximately twice as long a time in order to thaw a length of copper service pipe as is required for the same length of steel pipe.

Experience

Experience has shown that from 200 to 400 amperes (varying with the diameter) will thaw iron, steel or lead services in from three to ten minutes. Depending upon the character of the connections, the type of joints in the mains and other elements of resistance, the voltage necessary to force such a current flow through the circuit will vary from 10 to about 60 volts. To thaw mains, amperages of from 400 to 700 are likely to be required at times. In view of the larger area of metal in these pipes it is fortunate that cast-iron has high resistance to current flow, else it would be impossible to produce sufficient heat with any practical portable electrical apparatus.

To produce a current of 400 amperes at 60 volts requires about a 25 k. w. generator, although one with a capacity of 30 k. w. is better. The gasoline engine driving it should have a rated capacity of at least 50 per cent more in order to sustain the output for several hours in case difficult main pipe thawing is encountered.

If current is taken from the 2300 volt lines of the local power utility and is stepped down to 110 volts, the transformers should have at least a total of 75 KVA capacity if mains are to be thawed, because it is occasionally necessary to use higher amperages than the average stated and also to maintain the current flow for several hours. A 25 KVA transformer is usually ample, however, for the thawing of services. It has been observed that AC current is more effective than DC in thawing because the vibration set up by the former is of material aid. The necessary small amount of melting near the pipe surface takes place with less actual temperature rise in the pipe.

REGULATING WATER PIPING WITHIN BUILDINGS*

By STEPHEN H. TAYLOR

Superintendent, Water Department, New Bedford, Mass.

It is the opinion of the writer that sufficient attention has not been given in the past by water works officials to water piping and fixtures inside of the taker's premises.

Until last year, we in New Bedford have felt that when we assured ourselves that the service pipe to and including the meter were of proper material and properly installed our responsibility and jurisdiction ended; and, what was installed inside of that point was wholly the affair of the owner and his plumber. I think it is safe to say that most water works officials in this country have taken the same attitude.

In consequence, we find in many cases that faulty workmanship has been a result and inferior materials have been installed. In addition, sanitary fixtures are often of a design and so installed as to unwittingly introduce a danger to health through pollution of the water supply within buildings by siphonage or gravity backflow of polluted water from bowls and other fixtures to the water supply piping. Speculative and boom building has resulted in many buildings being piped with cheap materials and fixtures, installed frequently by incompetent workmen.

It is a well known fact that the surface water supply of New Bedford is rather active and quickly fills wrought iron and steel pipes with rust and tubercles. This condition exists also in many other communities. In spite of such knowledge, many buildings have been piped with this type of material, with the result that after comparatively few years, water cannot be drawn through more than one fixture at a time and that one delivers only a weak supply. Services installed by the Water Department in New Bedford are of lead, in sizes up to 1 inch; and, copper or cast iron is employed for the larger sizes. In most cases we have installed the service up to the meter, which is usually located in the cellar of the building.

When complaints of poor flow come to us we clear the tap and service line, if necessary, and prove that the supply is ample up to the meter and that the trouble is caused by rust choking of the steel piping inside the building. This means many unnecessary visits and explanations; which takes considerable time of our employes. When the owner finds that his only remedy for the trouble is to repipe the entire building, to say that he is somewhat disturbed, is stating the case mildly.

We have also found that modern fixtures frequently of such a design that polluted water from them can flow back into the water supply pipes either by gravity or siphoning in case the pressure is reduced by heavy draught on the lower floor of buildings, or wherever the water is shut off in either the building or in the street.

Water Board Drafts Regulations

In an effort to improve these conditions the Water Board adopted a set of rules and regulations, which became effective June 1, 1935, governing the installation of house piping, which we feel will benefit the water department—but, more especially the public.

The city ordinances places the supervision of hot water tanks and water heaters under the jurisdiction of the City Board of Health. That department works in cooperation with our department regarding this equipment and has established rules which require that such equipment be installed in a manner which will be safe and prevent forcing hot water back to damage meters.

The new regulations follow.

[Note.—At this point the author outlined those parts of the regulations which embrace the principal requirements pertaining to "Inside Piping and Fixtures." Believing that our readers may prefer to have before them the completed set of regulations, these are reproduced below (in full) just as they appear in the neat little brown booklet (3¾ x 6 in.) which is distributed by the New Bedford Water Department.—Editor.]

New Bedford Water Board Regulations Governing Water Service Supply Piping and Fixtures† June 1, 1935

(See separate pamphlet for sprinkler piping regulations)

Section I. Every water-taker shall pay the established rates for water supplied within the time and at the place specified upon bills rendered; shall at his own expense, keep the service pipes within his premises in good order and repair and protected from the frost; shall not allow the water to run to waste; shall not make any change in the service pipe between city main and meter, unless sanctioned so to do by the superintendent; shall not conceal the purpose for which water is used; shall allow the superintendent, registrar and persons authorized by them, or by the board to enter the premises supplied with water to examine the pipes and fixtures and ascertain the quantity of water used and manner of use, and shall indemnify the city for all damages it may sustain or be required to pay, in consequence of any injury resulting from any violation of these regulations by the water taker.

Section II. All applications for service supplies must be made by the owner of property at the office of the registrar in the form prescribed, stating the various uses to which the water is to be applied.

Section III. SERVICE FROM STREET—In every case the installation of the service pipe from the street main to the end of pipe where taker's stop with waste is installed by the plumber shall be made by the New Bedford Water Department and the charge to the owner shall be as specified in regulation adopted by the Water Board February 6, 1924, viz.:

For installing one service to each property from the main pipe to street line as follows:

For ⅝ in. service	$31.00
For ¾ in. service	32.00
For 1 in. service	39.00

In cases where permanent pavement is disturbed, the owner is also required to pay for replacing the same.

For secondary services, temporary services or for services larger than one inch in size, the entire cost of installation, including cost of re-surfacing permanent street pavement.

For all services on private property, the owner shall pay the entire cost of such work.

Section IV. Each service shall be provided with a satisfactory stop and waste cock with coupling (this stop shall be round way and of the same size as the service pipe) to be located always just within the basement wall, at the point where the service pipe enters, and the pipes within the building must be so arranged that the water can be drawn from them whenever there is danger of freezing. The department will not be liable for any damage resulting from a failure to observe this important rule.

Section V. No water-taker shall be entitled to any damages nor will any portion of a payment be refunded for any sudden stoppage of the city supply occasioned by an accident or otherwise, nor for any stoppage for the purpose of making extensions, alterations or repairs. In such an event the water-takers must guard themselves against the collapse of boilers and other injuries liable to result from stoppage of the water supply.

Section VI. No cross connections between the City supply and any other supply which is not approved as potable by the State Dept. of Public Health shall be permitted except those which are properly protected by double check valves of an approved type. Said check valves shall be approved by the Water Board and shall be regularly inspected at the expense of the owner of the property by a representative of the Water Department at such intervals as the Water Board shall determine.

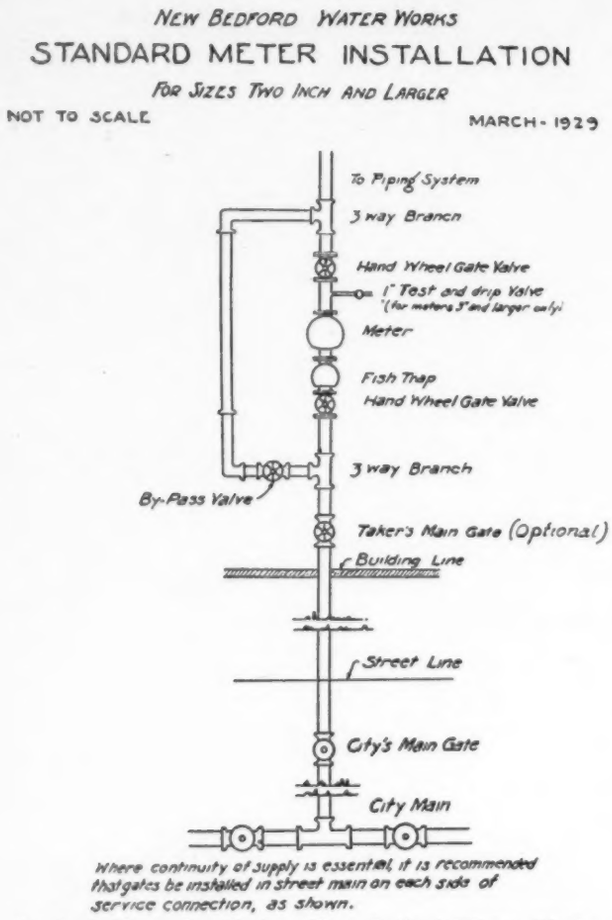
Section VII. METER REGULATIONS.

a. One meter of standard type and of same size as the supply pipe must be installed upon each service connection. It may be located between the curb stop and building or within building. If within building, it must be placed at a point adjacent to shut off, where pipe enters through foundation wall. If outside the building, it shall be installed in a satisfactory box or pit not less than 3 ft. x 4 ft. x 4 ft. deep. All meters 2 inches or larger shall be equipped with a by-pass capable of supplying the premises when the meter is removed for repairs or test. This by-pass valve to be kept sealed shut except when meter is out. (See Sketch.)

b. In all cases where one service connection supplies two or more separate consumers, or a block occupied by divers parties, only one meter will be used and the water rent as registered by said meter shall be charged to and payable by the owner of said premises or building. If additional meters are desired to ascertain sub-division or such supplies, they will be

*From Water Works and Sewerage.

†Regulations pertaining to inside piping and fixtures begin with Section VIII.



Standard Meter Installation, New Bedford Water Works.

furnished at the expense of the applicant, who must assume all responsibility of reading and maintaining same.

c. Owners of property will be given option of either purchasing a meter outright and paying for its installation, or of having city furnish and install same and paying an annual rental therefor.

d. The property owner must keep the meter within his premises easily accessible for reading at all times. The city will include all repairs due to ordinary wear in its rental charge, but in all such cases, the owner will be held responsible for proper protection of the meter from all damage which may occur due to freezing or from hot water backing from overheated house boilers or other causes. Property owners will be assessed the cost of repairs of every nature necessary to properly maintain the meter owned by them. In case payment of such charges is not made upon demand, the water will be shut off from the premises supplied, and will not be renewed until after such charges, including the additional sum of one dollar, to cover expenses of shutting off and letting on the water, shall have been paid.

e. The owner of property shall pay at the established meter rate for amount registered, whether used or wasted. The water department will not assume any responsibility for use of water within metered premises.

f. Should a meter fail to register for any cause, the quantity shall be determined and the charge made based on average amount registered by meter when in order.

g. After a meter has been installed, it will not be removed for purpose of rating the premises supplied on any other basis of water charged.

h. No meter shall be discontinued from the pipe, moved or disturbed, without permission from the water registrar, who will send a properly authorized person to attend to any change needed.

i. If a house becomes unoccupied, the owner or agent may have the water shut off and the meter removed during the period of non-occupancy by making a request therefor to the water department, and paying one dollar to cover expenses.

Section VIII. PLANS TO BE APPROVED—Plans of proposed new installations, extensions or alteration of existing systems, showing proposed sizes and materials, must be filed with the Water Board, and approved by said Board or its designated representative before starting work.

Section IX. INSIDE PIPING—All inside installations shall be made under the direction of a registered Master Plumber, except in manufacturing plants or other plants where competent pipers are regularly employed. Connections to supply water heaters, hot water storage tanks, heating and ventilating apparatus, cooling systems and power plant equipment and apparatus may be made by competent employes of persons regularly engaged in the business of installing such apparatus, subject to the inspection and approval of the Water Board. Each holder of a Master Plumber's Certificate of License shall register his name and business address with the Water Board on or before the first day of May in each year. Notice of any change in the place of business shall be given immediately to said Water Board.

Section X. INSPECTION AND TEST—On completion of the installation it shall be inspected and approved by the designated inspector of the Water Board before the water supply will be turned on to the premises. It shall be tested in the presence of the inspector at city water pressure.

Section XI. KIND OF PIPE—All water supply pipes and fittings, shall be of lead, brass, copper or other non-ferrous metal or composition, except in the case of pipes four inches or more in diameter, in which case, cast iron pipe properly coated and lined with material approved by the Water Board may be used.

In order that piping shall be sufficiently strong to withstand City pressure with a reasonable allowance for corrosion all pipes must comply with the following minimum specifications.

LEAD PIPE:

All lead pipe for water service shall be made from soft virgin pig lead without any admixture of scrap lead or any other material and shall weigh not less than

For	½	in. pipes	3 pounds per foot
For	⅝	in. pipes	3½ pounds per foot
For	¾	in. pipes	4½ pounds per foot
For	1	in. pipes	6 pounds per foot
For	1¼	in. pipes	7¾ pounds per foot
For	1½	in. pipes	11¼ pounds per foot
For	2	in. pipes	19½ pounds per foot

BRASS PIPE:

All brass pipe used for water supply piping shall conform with the Standard Specifications of the American Society for Testing Materials for "Brass Pipe, Standard Sizes" Serial Designation B43-23, with the exception of Paragraph 4 thereof. In place of the said Paragraph 4, the brass shall conform to the following requirements as to chemical composition:

Copper, minimum	59.00%
Lead, maximum	0.50%
Iron, maximum	0.07%
Zinc, or Zinc and Tin	Remainder

This change admits use of so-called "Admiralty" and "Red" brasses.

COPPER PIPE:

All copper pipe used for water supply piping shall conform with the Standard Specifications of the American Society for Testing Materials for "Copper Pipe, Standard Sizes," Serial Designation B42-23.

COPPER TUBING:

All copper service tubing used for underground piping shall conform with the Standard Specifications of the American Society for Testing Materials for Copper Tubing, Government Type K, Serial Designation B88-33. For interior piping copper tubing, Government Type L, is allowable.

Fittings for use with brass or copper pipes shall be of material and strength corresponding with the pipe used. All installations shall be made in a thorough and workmanlike manner satisfactory to the New Bedford Water Board.

Pipes which are to be concealed in partitions or otherwise shall be tested as specified in Section X before being concealed.

No pipes which have previously been used for other purposes shall be used for distributing water.

Section XII. PROTECTION—All concealed water pipes, storage tanks, flushing cisterns, and all exposed pipes or tanks subject to freezing temperatures shall be efficiently protected against freezing.

Section XIII. DISTRIBUTION—The water supply shall be distributed through a piping system entirely independent of any piping system conveying another water supply.

Section XIV. WATER SERVICE—The water service pipe of any building shall be of sufficient size to permit a continuous ample flow of water to all fixtures on all floors at a given time.

Section XV. SUPPLY TO FIXTURES—All plumbing fixtures shall be provided with a sufficient supply of water for flushing to keep them in a sanitary condition and shall be ad-

justed to prevent waste of water. The water from water closet and urinal flush tanks shall be used for no other purpose.

The bottom of flush tanks for water closets or urinals shall be above the overflow level of the fixture when drain is obstructed.

All flushometer valves for water closets shall be equipped with a vacuum breaker of a type approved by the Water Board.

The supply pipe for each tenement or bathroom shall be not less than ½" inside diameter and connect to the main supply pipe, which shall be not less than the size of the main service. The main service shall be carried full size to the point where the last branch is taken off in the basement.

Accessible shutoffs with waste shall be provided in the basement which shall separately control the water supply for each tenement and for each hot water tank.

Section XVI. SIZE OF PIPES—The minimum size of water-service pipes from main to the dwelling shall be five-eighths inch, and to fixtures as follows:

Sill Cocks	½ in.
Hot Water Boilers	½ in.
Laundry Traps	½ in.
Sinks	½ in.
Lavoratories	⅜ in.
Bath Tubs	½ in.
Water Closet Tanks	⅜ in.
Flushometer Valves for Water Closets	1 in.
Flushometer Valves for Urinals	½ in.

[Note: A copy of the application form, for Water Department approval of piping and fixture installations, may probably be had upon request to the author of this article—*Editor.*]

Some Results

It is interesting to note that in spite of the fact that no new building has been going on in New Bedford during the 8½ months since these rules became effective about 700 permits for alterations and replacements have been issued.

Two outstanding cases of potential pollution from back syphoning have recently come to the attention of our inspector. One was in a large High School; the other in a department store of importance. These cases and many others show the need of constant vigilance on the part of someone, and we in New Bedford have decided that the Water Department should assume this responsibility as there is a possibility that pollution from such sources may even get back into our mains by siphonage or gravity when it becomes necessary to shut off the street mains.

The inspection has been placed in the hands of a Master Plumber of long experience who has the respect and confidence of other master plumbers. He is a full time employee of the Water Board and has the complete cooperation of the plumbing inspector of the City Board of Health.

The new regulations have been in effect since June 1st, 1935, and the results have been very satisfactory. The master plumbers cooperate very well with us as it protects them against unfair competition of unlicensed men and inferior materials. The public gains by being assured of proper supply and approved water fixtures. The department gains by being relieved of many complaints which come about as the result of improper materials or workmanship.

As far as the writer knows, very few communities have made rules regulating water service piping and fixtures inside of buildings. No matter how complete the main distribution system and service connection may be, the consumer will not get the supply he is entitled to at his fixtures or the protection against pollution within his own property unless someone sees to it that proper interior piping and fixtures are installed in an approved manner.

Our City Solicitor has ruled that the supervision of the entire water supply (except water heaters and hot water tanks), up to and including proper fixtures, is within the jurisdiction of the Water Department.

Representative Water Rates

That where water is the dearest it has been made available at such comparative low cost to consumers is a situation stressed in its publicity releases to consumers by Los Angeles' Department of Water and Power.

What the Official Bulletin "Water and Power" has to say to Los Angeles water takers is of interest.

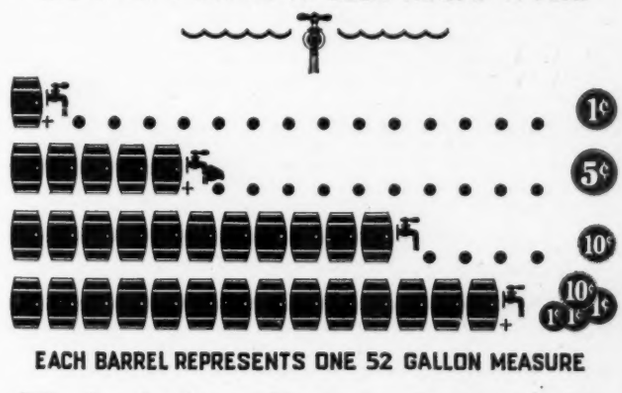
"Water and Power" has the following to say:

"Los Angeles consumers pay the low rate of 13 cents for 100 cu. ft. (750 gallons) of pure water brought in from mountain streams 250 miles distant. For the same amount of water the average charge in 183 of the larger cities in the United States is 18 cents."

The following rates charged by representative cities are cited in comparison:

San Francisco	28 cents	Youngstown, O.	20 cents
Pittsburgh, Pa.	25 cents	Miami, Fla.	19 cents
Indianapolis, Ind.	22 cents	Boston, Mass.	15.4 cents
Des Moines, Ia.	22 cents	St. Louis, Mo.	15 cents
Los Angeles	13 cents		

Any municipality which can show a rate below the 18 cents per 100 cu. ft. average in 183 representative American municipalities would do well to utilize the figures quoted, release the "story" to the local press and distribute reprints of this "news" with its water bills.



[*The above has been used by the Los Angeles Water Bureau to stress the cheapness of water at* 11 *barrels for a dime and no haulage to pay.—Ed.*]

AIR CONDITIONING IN RELATION TO WATER CONSUMPTION

By LOGAN L. LEWIS*

Newark, N. J.

While it may be true that air conditioning has but recently become of peculiar but important interest to water works authorities, it is by no means a novelty. The industry is some thirty years old. During the first twenty years of its life, application was limited almost entirely to industrial plants and, hence, few people knew of it. About ten years ago its application began to spread rapidly to theaters, department stores, restaurants and other buildings in which the public gather. This second phase of development brought improvements in equipment, made price reductions possible, and greatly broadened the market.

From an air conditioning point of view, every human being in Jones' store is a heater, giving off heat in both its sensible and latent form, or, with freedom of description, as dry and moist heat. Every light, every electrical device, every coffee urn is a heater. The rays of the sun heat the building structure where they strike it, and heat also flows in through it, because a lower temperature is maintained inside the structure. Therefore his system must remove heat and moisture when the weather is warm and add heat and moisture when the weather is cold.

For effectively removing heat, we must have a refrigerating machine of which there are many types, all of which must be provided with means for removing the effluent heat. This effluent heat usually is carried away wholly or partly by the water furnished, and requirements may be great. In winter requirements for water are minute. Thus, demand for water is a seasonal one and proportional to the quantity of heat which must be removed.

A simple way to get rid of this heat is to buy water from the water utility and pass it through his condenser to the sewer. If this were the only way to do it, water departments might well be concerned by the demand. But, in certain cities, the cost of water was high and the manufacturers of air conditioning and refrigerating equipment sought means of reducing water costs. And, so, economic forces began to stimulate the development of equipment which would reduce sales resistance by reducing the need for water where the rates were high, or where the threat of water shortage might restrict its use. This has borne fruit, so that there is available water conserving equipment which may, in some localities, reduce sales that water works managers would like to make. However, in other localities this improvement may prove a desideratum in reducing excessive demands.

The Economy of the Cooling Tower

The first stage of this development was the cooling tower—that slatted structure which you will recognize as the architectural abortion you have seen upon the roof of some local ice plant. This cooling tower is a means of heat disposal. The water passing through it is recirculated, being pumped through the condenser where it receives heat, and then through the cooling spray tower where it gives off this heat to the air. Some of the water is carried away by the wind, some of it is lost by evaporation, and that which is lost must be replenished from the source of water supply. This loss is quite small, so that the use of this cooling tower for heat disposal has cut the demand for water to less than 10 per cent of what it would otherwise be.

To be fair to the cooling tower, it must be said that much has been done to improve its appearance. The second stage was the development of the evaporative condenser, in which the functions of the condenser and the cooling tower have been combined. The features of water conservation have also been further improved thereby and the space occupied by equipment greatly reduced. This piece of equipment may be placed upon the roof of a building and appear as a small rectangle, or, if it is feasible to lead air to and from it through ducts, it may be tucked away in one corner of the machinery room.

Since there is no windage loss from the evaporative condenser, it requires less than 5 per cent of the water which you would otherwise furnish. Both the tower and the evaporative condenser are instruments for the conservation of water and are fully developed practically and commercially.

*Chief Engineer, Carrier Corpn., Newark, N. J.

Water Demands of Modern Equipment

What is the magnitude of this demand for water going to be and what will be its characteristics? Let us examine the demands for water of the several types of prevalent installations of air conditioning, which are given in Table I which accompanies this discussion.

B.t.u., or thermal units, per person will vary somewhat for each installation, but limits of variation are well known. Hours of operation per season can readily be set for maintenance of the desired conditions. Load factors, or the relation of average load to maximum load, are based on experience. Gallons of both maximum and average demand must be based on an average water temperature and an average balance between water and power. Hence, Table I is necessarily composed of figures which are admittedly controversial as to the interpretation of experience, for multifarious economic forces press in some localities for excessive use of water and in others for conservation thereof.

For a given electric power rate, cold water may throw the balance in favor of heat disposal entirely by water—warm water may do the opposite. Low power rates may favor conservation of water—high power rates, the opposite. A combination of high's of water temperature and power cost operate strongly in favor of heat disposal by evaporation.

The complexity of these economic forces becomes apparent when it is realized that power for air conditioning may cost from less than 1 cent per k.w.h. to more than 3 cents; that water may be purchased at rates varying from 45 cents per 1,000 cu. ft. up to $2.85—perhaps higher; that the temperature of the water coming from mains may range in summer from 56 to 85 degrees F.; and that pocketbook limitations to available capital may enforce the purchase of equipment which, being of low capacity, is above average in demand for water or power, or both.

But, let's continue our examination of the averages arrived at in Table I as they are carried forward in Table II. Three important facts become obvious.

First, that the demand for water is seasonal. It is high in summer and, as previously stated, insignificant in winter. An 120-day cooling season is typical of New York. In the South, it may exceed 150 days.

Second, that economic forces and restrictive regulations, such as are now applied in New York, did, in 1935, lead to extensive purchase of evaporative heat disposal systems. As a result, water consumption was cut by 60 per cent.

Third, that within the cooling season, the peak demand is far above average consumption.

Two figures in Table II are of such importance that they

TABLE I

DEMANDS OF SEVERAL TYPES OF AIR CONDITIONING INSTALLATIONS FOR WATER

VALUES ARE PER PERSON
SEASON OF 120 DAYS
WATER COOLED CONDENSERS

	BTU/HR.	MAX. DEMAND GAL./HR.	HRS. OPERATION PER SEASON	GAL./SEASON AT MAX. DEMAND RATE	LOAD FACTOR PERCENT	PROBABLE USE GAL./SEASON
RESIDENCE	4,000	40	2,900	160,000	30	48,000
TRAIN	1,400	14	1,200	16,800	50	8,400
OFFICE	4,700	47	1,200	56,400	40	22,500
LUNCH ROOM	1,600	16	900	14,400	50	7,200
RESTAURANT	2,000	20	1,200	24,000	60	14,500
DRUG STORE	2,000	20	1,800	36,000	60	21,500
THEATRE	1,000	10	1,500	15,000	30	4,500
DEP'T. STORE	1,600	16	1,200	19,200	60	11,500
AVERAGE	2,300			42,500		17,200

TABLE II

AIR CONDITIONING REQUIREMENTS FOR WATER

GAL./PERSON

THE FOLLOWING ARE "COLD AVERAGES", ADMITTEDLY CONTROVERSIAL AS TO THE INTERPRETATION OF EXPERIENCE.

	NO EVAPORATIVE CONDENSERS OR COOLING TOWERS USED.		BASED ON USE OF EVAPORATIVE CONDENSERS OR COOLING TOWERS ON 60% OF INSTALLATIONS. 1935 EXPERIENCE	
	IF MAX. DEMAND IS SUSTAINED.	PROBABLE USE	IF MAX. DEMAND IS SUSTAINED.	PROBABLE USE
PER SEASON OF 120 DAYS	42,500	17,200	17,000	7,000
PER DAY FOR SEASON OF 120 DAYS	350	140	(140)	60
PER DAY FOR YEAR 365 DAYS	120	50	50	(20)

have been encircled. Note carefully that they are *not* the *per capita* consumption that water works men are accustomed to using.

Air-conditioning-wise, they will become per capita consumption if and when air conditioning installed and operated for the entire population served by the water system. This does not mean that every building in a city must be completely conditioned. It does mean that the sum total of the number of people upon which the capacity guarantees of the systems are based has reached the sum total of population. In still other words, it means that there will exist an air conditioned spot for each and every person in a city, and no more.

If air conditioning sales double every four years, at some time in a period between 1945 and 1950 the per capita demand upon water systems for modern air conditioning may become:

(1) Maximum rate—35 gallons per day per capita.

(2) Average rate—5 gallons per day per capita.

Provided the present practice of using evaporative condensers and cooling towers is maintained. But if evaporative condensers and cooling towers be used exclusively from now on and be substituted for existing condensers, now wasting water, then these two rates would be cut to:

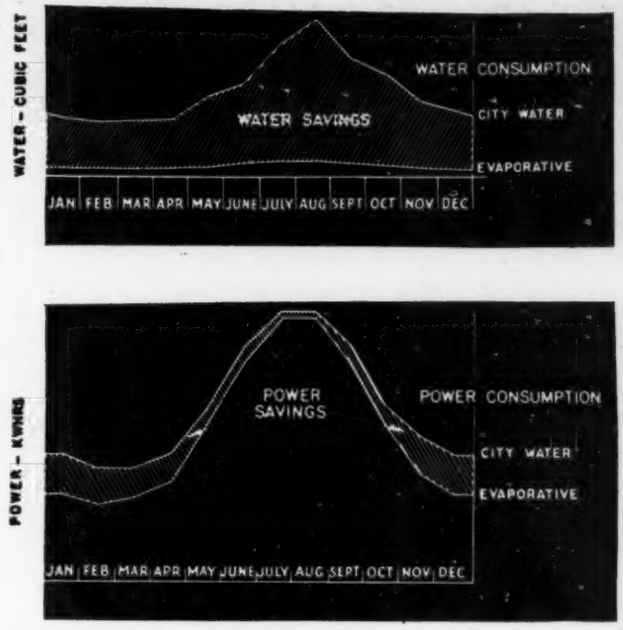
(1-a) Maximum rate—23 gallons per day per capita.

(2-a) Average rate—3 gallons per day per capita.

Water works managers may be divided into two groups:

1. Those to whom air conditioning offers an opportunity to sell more of their product.

2. Those to whom any increased demand will present a serious problem, and those who may now be unable to meet existing demands if rainfall is below average.



Water Conservation Made Possible by Use of Modern Evaporation Condensers

My conclusions are:

(a) With respect to Group 1: The maximum demand of 23 to 35 gallons per capita per day may overtax existing water works pumping equipment or, if not that, the capacity of the mains at certain focal points.

(b) With respect to Group 2: Their inability to assure a continuity of supply, either at present rates of consumption, or at present rates plus 3 to 5 gallons per capita per year average, or to pump and distribute as in (a), should be faced squarely as the facts stand, and proper restrictive measures instituted.

(c) Generally: That the number and complexity of factors are such that the problem will not yield except to analysis of a specific survey.

(d) That it is to our common interest to know and face the facts; and, worth our mutual effort to obtain them.

Terminology in Pumping*

Static Head

Static Head is the vertical distance in feet beeween the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head, is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

*From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

REMOVING WATER FROM MAINS WITH COMPRESSED AIR*

Eliminates Pumping, Wet Trench, Loss of Time

By ROGER W. ESTEY[1] and NELSON BOARDMAN[2]

Danvers Water Works, Danvers, Mass.

Often in the repairing of mains or replacements of old pipe lines, the question of time is of paramount importance. The removal of water from these mains is many times a lengthy and most disagreeable part of the entire procedure. It often takes as much time to eliminate the water as it does for the connecting in of the new material.

Of course, today we have gasoline-driven diaphragm and centrifugal pumps that remove the water much faster than the old-fashioned hand methods. But, even with this more efficient and faster way of removing the water, it does not overcome the objectionable features, of water gushing out when the pipe is being cut in the trench. Sometimes where there are no blow-offs to remove the water entirely or take off some of the pressure that may be caused by the irregular contour of the ground, removing a piece of pipe from the line is a wet and disagreeable job. Besides this, all of the men have to be equipped with boots.

Another worry that goes along with such a job is the attention that has to be given to the soil conditions. If the nature of the soil is sandy and gravelly, any great amount of water in the trench may cause a slight washing or wearing away of the bank, causing either one or both banks to cave in. This is a very important part of the work to watch, because in many instances it is not possible to shut the water off any length of time without causing great inconvenience to the customers, and then there is always the fire hazard which must be given consideration. Any caving-in of the banks therefore naturally increases the time to complete the work. When the soil is clayey, water in the trench makes a nasty mess to work in, and it is nearly impossible to keep the pipe and fittings clean.

There have been many times when we have thought over the above undesirable conditions and wondered if there wasn't some way whereby this could be overcome. In several places we cut in blow-off lines, but since there are so many places requiring blow-off lines, this method seems both impractical and too costly.

Compressed Air Considered

Three things came to our attention that caused us to give consideration to the use of compressed air to remove water from the mains. One of us stopped in at a local garage, and while there a customer came in and asked for a gallon of denatured alcohol. The proprietor took the container and went over to a barrel and placed the container on top of the barrel, under a riser pipe, and opened the faucet. Much to our amazement, the alcohol came out so fast it was only a moment or two until the container was filled. After the transaction had been completed we inquired, "How is it that you get that pressure from the alcohol barrel?" He informed us that every now and then he would take the hose line used to pump up tires and put it on to another connection, on top of the barrel, and build up an air pressure in the barrel. When opening the faucet the alcohol would gush out. That gave me an idea.

[1]Superintendent and [2]Assistant Superintendent.
*From WATER WORKS AND SEWERAGE, June, 1936.

Compressor Connected to Hydrant

Removal of Water from a 12-In. Main

At about the same time one of us was called in at a private home which had a well supply. They had purchased a storage tank and pump unit. The tank contained approximately a thousand gallons. After the pump had filled the tank so that the gauge would indicate 60 lbs. it would only require about an hour before the pressure would drop so low that no water could be obtained in the house. It indicated that there must be a leak somewhere in the line. After testing for about an hour the leak was located out in the yard. This was later dug up and repaired. But what interested us was that almost 80 per cent of the tank from the bottom toward the top had a sweaty appearance on the outside and the upper part was dry. This indicated very conclusively that the upper 20 per cent was compressed air, and, from this, energy was obtained to force the water out of the tank and into the house.

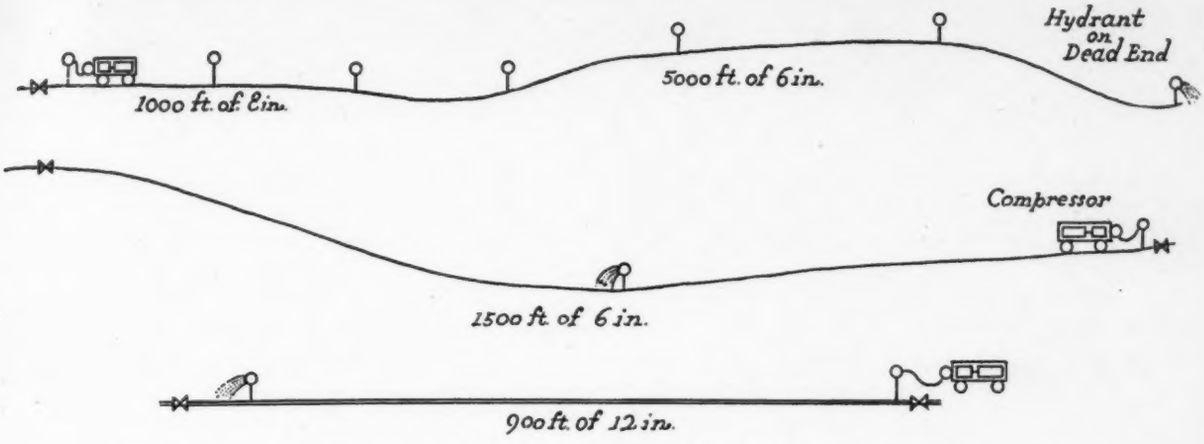
Now the third experience with compressed air followed almost immediately when we received a complaint from a customer that was receiving a large quarterly (metered) water bill. Since the bill was approximately $40 per quarter, and as the estate being supplied was of such large proportions, we assumed that it was legitimate consumption.

We immediately made an inspection. The pipe line consisted of about 1,200 feet of 2-inch cast iron cement-lined pipe with the meter in a pit at the property line. We inspected and tested the entire line with the exception of a swampy area of about 100 feet across it. We could not find a resemblance of a leak. The only place left was the swamp, which was covered with water. We thought we would try compressed air. We got our air compressor and placed it near the meter pit. We disconnected the meter and connected the air hose to the outlet pipe of the meter setting. We started up the compressor and turned the air into the pipe line and in about three minutes bubbles appeared out in the swamp water. We marked the spot with a stake and later, when the water receded, we dug it out and found the hole in the pipe that was responsible for the waste.

So, from these experiences, we felt that by applying compressed air into a pipe line and having a hydrant open, it would force the water out. With this thought in mind, it was not long before we had an opportunity to try out our idea, and it exceeded our fondest expectations. We have used it several times lately, so successfully that we have told some of our friends about it and they too are highly pleased with the results.

Procedure Developed

In making connections, the lay-out must be looked over carefully to find the highest place possible on the section to be emptied and there connect in the air. Then the hydrant at the lowest point must be opened wide. It is not necessary to close off any services.



Sketch Showing Three Conditions Wherein Water Removal with Air Compressors Was Successful

When the district is shut off and the air compressor is connected, either to a hydrant or house connection, and the relief hydrant is opened, turn the air into the main, and almost instantly the water will start coming out of the waste hydrant. The compressor that we employ normally indicates 100 lbs. when the tank is full. The pressure will almost immediately drop from 100 lbs. to 60 lbs., and sometimes will gradually drop to 40 lbs., depending upon the size of the pipe. The larger the pipe, the greater the drop in pressure.

Some Experiences

Our outstanding performance was in connection with the emptying of a long line consisting of 1,000 feet of 8-inch pipe and about 5,000 feet of 6-inch, terminatnig in a dead-end district.—See sketch. In this section we had planned several changes and we had seven holes dug. One was for the laying of a 6-inch line across this street. Three hydrants had to be moved back and gates cut in on the branches and three extra gates cut into the main line. We connected up our compressor to the first hydrant

Removing Water from 6-In. Main by Air Pressure. Section 480 Ft. Long Emptied in 3 Minutes

and opened up the last hydrant at the end of the line. We closed off the district at 8 a. m. and then turned the air into the line, and in thirty-five minutes the water was forced out, and air then came out of the last hydrant, indicating that the water was removed. During this thirty-five minutes the water came faster and faster, due to the fact there was progressively less water and less weight to push with each succeeding minute.

During the day we cut into this pipe line in seven places and none of the openings had enough water in them to even require common rubbers over the shoes. In fact, six of them were *completely* dry. You can readily see the value of this procedure. It is inexpensive, quick, and in most instances a dry trench can be had. You can well imagine how long it would have taken to complete the job if the cuts were made and hand or gasoline pumps had been used in the removal of the water from the trench.

Another experience on a 6-inch line 1,500 feet long was interesting in that a hill was within the area. Half way along the line at a low point there was a hydrant which was used to remove the water. At one end of the line was another to which we connected our compressor line. This hydrant was about 5 feet higher than the hydrant we were to blow the water out through. At the other end of the section of line was the gate, located at a point about 25 feet higher than the hydrant which was to be used to blow out the water.—See sketch. After closing the gate the two hydrants were opened and the compressor turned on. In a very few minutes the water ceased to flow and air came out of the hydrant. The compressor was closed off for about a minute, which allowed the water on the hill to flow down into the lower area. Then the compressor was turned on and more water gushed out. This procedure was repeated several times until no more water came out of the hydrant. The tee was then cut into the line and pipe laid to a gate. At no time did water come out of the cut pipe.

This scheme has also worked out satisfactorily on a 12-inch pipe line of about 900 feet in length and nearly level.

We have also located the ends of our two intake suction lines from our two sources of supplies. At our main station we have a connection around our well house connected into our discharge system in order to reverse the flow of water in the suction line. There was a connection wherein we could connect our compressor. After closing the gate on the suction line in the well house the air was turned on and bubbles appeared all along the line for about 300 feet out into the lake. When the air reached the end of the pipe it then came to the surface, causing the water to bubble up sometimes 2 feet above the surface. It showed very conclusively the location of the pipe and the end of it.

This method of removing water from pipe lines has eliminated all physical effort in securing a dry trench and has materially speeded up the work. It is inexpensive and almost always leaves a dry pipe and trench.

WATER WASTE SURVEYS

By A. D. STALKER*

Ottawa, Canada

Waste control, as a subject, can be divided very conveniently into two parts: First, that having to do with wastage which takes place inside houses and other buildings; and second, that concerned with wastage from the underground portion of the distribution system.

Meterage as a Remedy

By far the most effective method of dealing with the wastage that takes place inside buildings is by having services 100 per cent metered. The person who has to pay for water through a meter can generally be depended upon to be economical in its use. To make the watertaker pay for the water he wastes, will reduce that waste to a minimum.

In cities or towns where none, or only a small percentage of the services are metered, the control of waste from defective plumbing fixtures is much more difficult. Systematic house-to-house inspection, regularly maintained by a permanent staff of inspectors, will prove a great aid in keeping this class of waste within reasonable bounds. These inspections must be frequently repeated, and to be effective must be supported by strong laws and good plumbing ordinances.

In Ottawa when defects in plumbing fixtures are located by any one of the inspectors, the owner of the property is given 48 hours in which to make the necessary repairs. The inspector re-examines the premises at the expiration of the 48 hours, and if repairs have not been made, the service is shut off, and before it is again turned on repairs must be effected, and the owner is compelled to pay the sum of $1.00 as a charge for the services of the turnkey.

The public in general seems to think that the information contained in educational literature dealing with the importance of attending to small leaks and wastes should make a great impression—on somebody else. The value of this type of waste-control work is debatable. The writer's opinion is that the results obtained are not worth the trouble and expense of getting up and distributing the literature. *The only cure for waste due to carelessness is metering.*

The Pitometer

The second phase of waste reduction has to do with the location of leakage from the underground portion of the distribution system. To find the leaky parts of the underground system, a survey must be made to ascertain where the water goes after leaving the pumps, and what parts of the system receive excessive quantities. This can be accomplished by means of a pitometer.

The pitometer is an instrument that adapts the "Pitot" principle to the measurement of water. Two tubes enclosed within a metallic sheath are introduced into a water main through a 1-in. corporation cock. The tubes are set in such a position that one orifice faces directly up-stream and the other directly down-stream. They are connected by means of rubber tubing to the two legs of a glass U-tube containing a liquid of a specific gravity higher than water and which will not mix with it. The difference between the pressure on the downstream and on the up-stream orifices, which is the pressure due to velocity, causes a deflection of the liquid in the arms of the U-tube, and from this deflection the flow is calculated.

The prism photo recording pitometer makes a continuous photograph of the U-tube fluctuations upon a sheet of sensitized paper attached to a drum revolved by clock-work. The drum can be geared to complete a revolution in 12, 24 or 48 hours. From this photo record the flow through the main can be ascertained for any time during the gauging.

To measure accurately the flow through mains with the pitometer, the ratio of the mean velocity to the center velocity must be established, as the orifices of the instrument are set at the center. This ratio is called the "pipe coefficient" and is established by traversing the pipe. A pipe traverse is made by taking readings of the velocity at intervals across the pipe sufficiently close together to make a smooth curve when plotted. The pipe section is divided into rings of approximately the same area. The mean velocity of each ring in feet per second multiplied by the area of the ring in square feet, gives the ring volume in cubic feet per second. The mean velocity for the whole pipe section is the total of these ring volumes divided by the area of the pipe. The mean velocity divided by the center velocity is the pipe coefficient. On large mains it is desirable to traverse the pipe on two diameters 90 degrees apart and in the same plane. By using two rod meters, one can be left at the center of the pipe and the traversing done with the second, and readings taken when the center velocity is the same in each case. The pipe coefficient is the same for all velocities in the same pipe at any particular point, and it is upon the discovery of this principle that all pitometer gaugings are based.

How Pitometer Survey Is Made

A pitometer survey should properly start at the pumping stations, and the discharge from the pump checked. When this has been done, I think it good practice to test all trunk or feeder mains before dividing the system into districts. These mains taken separately can be quickly done, and the distribution of water through that part of the system fed by them is interfered with for a much shorter time than would be the case if they were to form part of a district. Furthermore, trunk mains are usually so spaced as to form excellent district boundaries.

More accurate results can be obtained if the pitometer tap is placed on a small main feeding into the trunk main than would be the case if the tap were to be placed on the trunk main itself, as a flow that would cause scarcely any deflection of the liquid in the U-tube if the tap were on the large main, would cause a sufficiently great deflection to give an accurate measurement of the flow if the tap were on the smaller main. The tap may be placed in such a position as to serve as a gauging point both for the trunk main and one of the districts.

The next step is the dividing of the system into districts. This work must receive careful consideration. A district should be of a size that can be conveniently sub-divided in one night during the hours of minimum consumption, and the boundaries laid out with a view to causing as little interference as possible with the circulation through the balance of the system. The gauging point should be on a main of such a size that a velocity of about 4 ft. per sec. would supply the maximum normal demands of the district, without any allowance for leakage. This velocity will give a deflection of about 17 in. on the U-tube, using a liquid of 1.25 specific gravity. The maximum consumption would not be likely to cause a velocity great enough to blow the liquid out of the tube, and the minimum consumption would cause a fairly high deflection. When the district is first gauged, a velocity higher than the above will probably be recorded ,and a heavier liquid might have to be used. The idea behind choosing a main of this size is to ensure a deflection high enough to give an accurate measurement of the flow when all leaks have been stopped.

It is necessary that those entrusted with waste reduction should become thoroughly acquainted with the conditions that exist in the various districts. The population and how it is distributed, and whether the area is industrial or residential, must be known in order to determine what quantity of water would be sufficient for its needs.

If the survey being made is an original one, a 48-hour record should be taken, including a Sunday if possible. Very careful records should be kept of all flows recorded and work done, and of any peculiar or unusual conditions that may be found to exist, as this information will, without doubt, be of great assistance in later surveys. Weather conditions and any circumstances which might affect the consumption of water should be noted.

When the flow is to be gauged, the district is cut off from the rest of the distribution system by closing all the valves on the boundaries, excepting on the pipe to which the instrument is connected. To make sure that the valves are holding properly, and that no water is getting in, either through them or through services that may be joined up inside buildings and connected to mains on both sides of a boundary, the main feeding the area enclosed should be closed and a hydrant at the highest point within the boundaries opened. If the hydrant is not off, the point at which the water gets into the district must be located, and

*Prin. Asst. Water Works Engineer, Ottawa, Ont.

THE NATIONAL WATER MAIN CLEANING COMPANY

Contractors for Cleaning of Water Mains
Hudson Terminal Building, New York, N. Y.

The fact is well known that most water mains are continually decreasing in carrying capacity. As they become more clogged more pressure must be exerted to keep the flow up to normal; or, if the system runs by gravity alone, sooner or later more mains must be purchased, or new sources of supply, or both, or the time will come when there will be insufficient flow to take care of the city's needs.

NATIONAL METHOD

UNLESS—

You clean the mains by THE NATIONAL METHOD, to restore them to CLOSE TO 100 PER CENT OF THEIR ORIGINAL EFFICIENCY AT A SMALL FRACTION OF THE COST OF ANY OTHER METHOD OF KEEPING THE WATER SUPPLY UP TO NORMAL.

What Causes These Mains to Become Clogged?

The causes may be divided into three classes—corrosion, growths (both vegetable and animal) and deposits, or sedimentation. Year after year the incrustations and deposits on the pipe interior get thicker and thicker, until the effective diameter of the pipe has been materially reduced.

How Does One Recognize the Fact that the Mains Need Cleaning?

In some cases the low pressure in districts indicate this. In other cases, the increased power needed at the pumps is an indication of the reduced carrying capacity of the mains. Occasionally, an unpleasant taste or odors become evident. This is a source of ill-health sometimes.

Let us suppose that it is definitely known that the mains need cleaning.

Why Choose the National Method?

Because the National method is quick and inexpensive. Because its field staff consists of experienced superintendents who can give you a satisfactory job at a minimum of expense, and with a minimum of discomfort and disruption of service.

You may furnish LOCAL LABOR if you desire. The National Water Main Cleaning Company supplies the equipment, and an experienced superintendent to supervise the work.

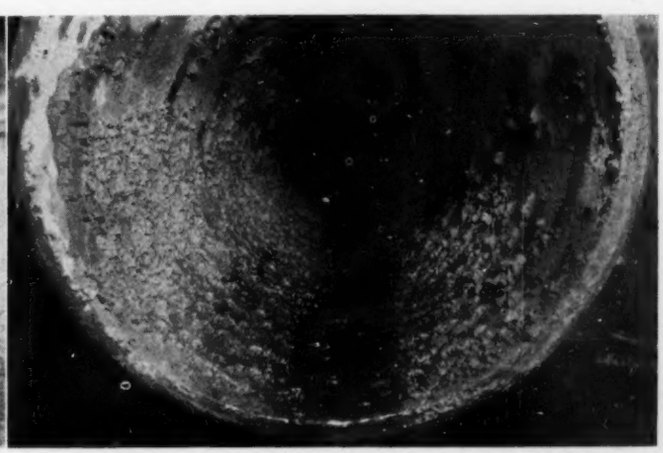
THE COST

No general figures of cost can be given. In making up an estimate of the cost of any water main cleaning job, it is necessary to take into consideration the following items:

1. Location of work
   (a) Transportation charges for men and equipment.
   (b) Location of work—country or congested district.
2. Labor conditions
3. Amount of work
   (a) Size of mains to be cleaned.
   (b) Number of feet of each size.
4. Layout of mains to be cleaned
   (a) Location of valves, and time required for complete shutoff.
   (b) Whether pipe must be cleaned in short stretches or long, because of pipe layout or condition.
5. Water pressures available
6. Depth of pipe and nature of digging

Let the National Water Main Cleaning Company give you a figure on the cost of cleaning the water main in your city. Send complete description of the conditions, and we will furnish you a quotation without obligation.

20" Main in a Midwest City Before Cleaning.



When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable.

the flow stopped. When it is assured that the whole supply passes through the main to which the instrument is connected, the district is ready for the taking of the record. Precautions should be taken to prevent street flushers drawing water from hydrants located within the district boundaries while the record is being taken. It is advisable also, to have a man with a valve key stationed at a fire hall either in or convenient to the enclosed area, so that valves could be opened with as little delay as possible in the event of a fire breaking out. If a fire occurs in a district while the flow is being recorded, the record will be ruined, and opening the boundary valves cannot make it any worse.

If the record taken indicates that an excessive amount of water passes the gauging point, and that the flow remains high during the hours in which very little water would be used, the district should be sub-divided. For subdivision purposes the mechanism revolving the drum of the pitometer is geared to complete a revolution of the drum in twelve hours. This will give a movement of an eighth of an inch in five minutes.

One method of sub-dividing is to divide the whole district into sections as small as the spacing of the valves will permit, and then closing a section down for a short period (at least five minutes) and re-opening it, and repeating this operation with other sections, until all have been shut down. Another method is to start at the boundaries and work towards the instrument, gradually reducing the size of the district, and as the new boundary valves are closed, the old ones are opened. The method used will depend on the conditions that exist in the district. With either method, the time each shutdown is completed must be noted. It is important that all valve operations should be checked over before leaving the district, to make sure that no valves are left closed.

Locating the Leaks

When the subdivision record has been interpreted we will know the quantity of water each section of the district received. The sections that receive excessive quantities should be carefully gone over and the reason for the large flow ascertained. It is a good idea to have a plumbing inspector make a special examination of the fixtures in all buildings in these areas. If this inspection fails to account for the flow, it is assumed that the cause is underground leakage.

There are a number of methods usually employed to give the exact location of underground leakage. The one most generally used, and the one by which a great majority of leaks are found, is by sounding. There are a number of instruments on the market devised to help in picking up sounds, and those that I have used have proven of great assistance. The procedure is to sound all the valves, hydrants and services in the suspected area, and sometimes it is possible to get closer to the source by driving rods down to the main. It is remarkable what an experienced man can accomplish by sounding. In a great many cases he can not only tell where the leak is, but its nature—whether it is a blown joint, a split main, or a burst service pipe.

There are, however, a number of cases in which the sounds picked up are confusing. Where there are two or more leaks close enough together for the sounds to overlap, it is difficult to isolate the sound from one leak and trace it to its source. Leaks that discharge under water produce a sound that is often misleading. Then there is the abandoned service that has not been properly blanked at the main.

Other methods used in conjunction with sounding include testing the pressure at different points until the point of minimum pressure is located; noting the flow in sewers at the manholes; pounding the road surfaces to endeavor to locate cavities beneath the pavement, and searching in cellars and excavations for dampness.

If the above expedients fail to locate the leak, the primitive of digging is resorted to. It is quite probable that the first hole put down will not be in the right place, but from the conditions that exist at this point, a second hols is usually all that is necessary.

Water appearing any place should be looked on as a possible leak, if the reason for its appearance is not apparent. The following is offered as an illustration: Some years ago, this city had a serious epidemic of typhoid fever. Water from any source other than the city mains was in great demand. During this time the writer noticed people drawing water from what appeared to be a spring located at the bottom of a hill. Those familiar with the locality insisted that this spring had always been there, and the city had had a sewer installed to carry off the overflow from it. A sample of the water was analyzed and the analysis showing that the water was very similar to that supplied by the city, the area in the vicinity of the spring was examined. At the top of the hill a 2-in. service that had been installed some thirty-odd years previously, was found to be running full bore. This was stopped and the "spring" immediately dried up.

Other Duties of Waste Reduction Department

In addition to the work outlined above, it is the duty of the department in charge of waste reduction to attend to all cases of flooding of cellars. The first thing to be done in these cases is to find whether or not the water department is responsible. In most cases a test of the electrical conductivity of a sample of the water is sufficient to decide. If the result of this test is not conclusive, an analysis of the water is made, and if it shows that the water comes from the mains, the leak is located by one of the methods mentioned above.

When serious breaks occur in the distribution system they usually give plenty of surface indication as to their locality. These are attended to by the trouble department. Bad breaks do occur without giving such indication, however, and these are followed up by the waste-reduction department. In such cases, the department first gets in touch with all the fire halls in the city, each of which has a pressure gauge installed, to find if possible an area in which the pressure has dropped. If no indication is given in this way, men are sent out to go over those parts of the system where it would be possible for the water from such a break to escape without surface indication. To know where to send the men requires an intimate knowledge of sub-surface conditions throughout the city. Pipes crossing waterways and mains in rocky sections through which large sewer or other excavations have been cut, should be sounded, and if the leak still remains unlocated, short readings of the flow to districts is resorted to.

Blotting Out Waste

Safe Water
delivered night and day
Costs Less
than anything else you buy
· · *but* · ·
Don't Ignore Leaks!
* * *
Satisfied customers are worth more to us than revenue secured from water uselessly passing through meters.
INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressure without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

MAINTENANCE OF VALVES AND HYDRANTS

By CARL A. HECHMER*

Hyattsville, Md.

It is surprising, especially in small towns and villages, how little attention is given the maintenance of gate valves and fire hydrants on their water systems. The need of good engineering advice and design is recognized and is compulsory in almost every state. Practically every state health department has a law compelling the submission of plans for approval before a water system can be built. The question of good materials is also generally given the utmost consideration and the best valves and hydrants obtainable, in the judgment of those in charge, are purchased and put into the water system. In many instances they are promptly forgotten until an emergency arises and quick, sure operation is necessary. Unless valves and hydrants are given regular attention and properly maintained the water works superintendent has no assurance that they will function properly. This fact applies to any make of valve or hydrant or to any other mechanical device or piece of machinery. Unfairly, the failure reflects on the designing engineer or the manufacturer of the material, and the local department is given a clean bill of health.

Valves

All valves on a water distribution system should be inspected once each year. This is the minimum requirement of the Fire Underwriters' Association. However, semi-annual inspection is advisable, if finances will allow it. Not only will the mechanical condition of the valve be assured, but valve boxes covered by paving material or earth will be located and reset ready for immediate operation in emergency. This is especially true in rural and suburban sections with a large percentage of unpaved streets. When a large leak occurs, excitement prevails and considerable time may be lost in locating a valve box. Occasionally a large stone or stones are found down in valve boxes and these conditions are revealed on inspection and removed. In case the valve has to be dug up, uncovering the valve, it is advisable to install new packing in the packing gland, which will prevent digging it up for repacking for a long time. Always repack a valve when it is uncovered for any repairs. Packing is cheap and easily installed while the valve is exposed. To dig up a valve just to stop a packing leak is an expensive operation. Inspection also locates valves which were carelessly or accidentally left closed. Any water distribution system is weakened by gate valves being closed when they should be open.

How a Valve Inspection Should Be Made

In addition to the box inspection, a valve inspection should proceed as follows: First set the valve key on the valve nut preparatory to turning the stem. Pour a small quantity of kerosene or diluted automobile crankcase drainings down the valve key stem. The oil will run down the key to the operating nut, thence to the valve stem and lubricate the valve stem against the packing gland. Finding its way into the packing gland, the packing will be softened and revived. Then operate the valve up and down several times, bringing the gate down into the groove hard each time and then opening the valve about one-quarter way. Valve troubles, preventing complete shutdown, are usually caused by the accumulation of sediment under the seat. Each time the gate is pushed down into the groove a small portion of this sediment is pushed out the sides. The high velocity of the water through the partly opened valve removes what is pushed out and the operation is repeated until the groove is sufficiently cleaned to allow the gate to seat properly. This procedure is especially recommended when valves fail to hold when attempting a shutdown. Of course, if the groove is filled with large stones or jointing material, the valve must be dug up and taken apart for repairs. The writer once operated a 16-inch valve up and down thirty times and secured a perfectly tight shutdown. The valve had not been operated for a long time having been declared worn out, since it always allowed a large volume of water to pass with the gate turned down hard with levers on the key.

In operating the valve a check should be made of the number of turns on the stem. Generally, for the same size and make of valve, the number of turns to close or open the valve completely is the same, and a check can be made to see if the stem is bent, preventing the valve from completely closing or opening. Either condition should be corrected, as partly open valves weaken the system and, obviously, partly closed valves will not shut off the water.

If the valve stem can be turned around and around with no apparent effect on the gate, the stem is broken and must be repaired.

Geared valves, usually set in manholes, must be given special attention on inspection. The gears should be cleaned with a wire brush and greased with a light clinging grease. The stuffing box should, of course, be examined, and the by-pass valve should receive the same attention as the smaller valves on the distribution system.

Fire Hydrants

Proper care in the installation of a fire hydrant is necessary and makes maintenance less expensive. Proper drainage of the hydrant barrel after the main valve is closed is essential to prevent freezing of the hydrant in northern climates. The best method is to provide a bed of crushed stone or gravel around the bottom of the hydrant. The amount of stone necessary is dependent on the nature of the soil. In loose sandy soils a much smaller drainage bed can be provided than in a clay soil that absorbs water very slowly. A safe margin is to provide sufficient area to allow the drainage of an amount of water equal to twice the contents of the hydrant barrel. Connections are often made direct from the hydrant drain valve to the sewer. However, there are two serious objections, first, the cost and, second the direct connection between a sewerage system and a domestic water supply, even though the possibility of contamination reaching the water in the mains is remote. Generally water mains are laid on one side of the street and sewers on the other. Hydrants are installed at the curb on the same side as the water mains to shorten the length of the lead. To connect each hydrant drain across the street to the sewer would prove much more expensive than providing a stone drainage bed.

Fire hydrants must be inspected at least twice each year, in the spring and fall. Four inspections annually should be made, if possible, and this number of inspections is advocated by the Fire Underwriters' Association. In high value districts, weekly inspections are often made during extremely cold weather. Arrangements should be made between the water department, the fire department and any other possible users of hydrants to report to the water department immediately after using a hydrant during freezing weather and an immediate inspection made to insure the good condition of the hydrant. Use of hydrants by private individuals or contractors should be allowed only by special permit, and the daily charge made high enough to permit daily inspection during freezing weather. During mild weather the inspection charge can be reduced, as weekly inspections are sufficient.

Valuable data may be secured by the fire hydrant inspection by measuring the static pressure, the residual pressure with one nozzle open, and the flow of water from the hydrant. [See artitcle on making hydrant flow tests (Wilson) elsewhere in this issue.—Ed.] Weak points on the distribution system can thus be determined and improvements due to new installation readily noted. System weakness due to unknown closed valves is also discovered and can be corrected.

Procedure for Making a Hydrant Inspection

The following procedure is suggested for making a hydrant inspection:

First make a physical examination of the hydrant, noting the condition of the operating nut, the nozzle caps and chains, and the general appearance of the hydrant. Then listen for leakage with an aquaphone placed on the operating nut. Then with the nozzle caps on tight open the hydrant valve. If static pressure readings are to be taken, replace one of the nozzle caps with one connected to a pressure gauge. Note if all the nozzles are tight in the hydrant and whether the drain valve has closed properly. If the drain valve has not closed water will appear around the barrel of the hydrant on the outside. Then close the main hydrant valve and take off one of the nozzle caps. Observe the rate of drainage of the barrel to determine whether any obstruc-

*Engineer of Distribution, Washington Sanitary District.

tion has entered the drain valve. To clean the drain valve replace the nozzle cap and crack the main valve. As it requires about three full turns open on the main valve to completely close the drain valve on most makes of fire hydrants, the latter is still open on two turns. The full pressure of the water in the hydrant generally will push out any obstruction in the drain hole and the jet effect of the water through the hole will cut away the stone or earth which has packed around the outside. This simple remedy will eliminate the necessity of digging up the hydrant, in most cases, to correct drainage troubles.

With one nozzle cap off, open the hydrant and thoroughly flush out the water in the lead. At this time the observation of residual pressure and rate of flow should be made. Then close down the hydrant slowly. If the hydrant fails to close off entirely, the trouble is probably being caused by an obstruction under the main valve. Do not put extra leverage on the hydrant wrench, but open the hydrant up again and then close it, repeating the operation several times. Do not attempt to close down beyond the point where the obstruction prevents the main valve from seating properly, as the obstruction will become embedded in the main valve and connot be flushed off, or the valve seat will be damaged. Both valve and valve seat are damaged by attempts to force closing against obstructions. Foreign matter can generally be dislodged by flushing and it is then not necessary to dismantle the hydrant.

After the hydrant is closed and the rate of drainage checked, the stem should be oiled and the nozzles greased with a graphite grease. This kind of grease will not wash off and it prevents the nozzle caps from sticking.

Inspection Records

Record of the inspection should be kept on a field sheet. The location of the hydrants to be inspected can be entered on the sheet in the office. These will allow correct routing and prevent skipping any hydrants. The information on the field inspection sheets can then be transferred to a permanent record card in the office. A card should be in the file for each hydrant, stating the size, make of hydrant, and information regarding pressure at the hydrant. The date of each inspection should be entered on the card together with the observed pressures and rate of flow. Necessary repairs and their costs can also be recorded on the card and a history of each individual hydrant is easily obtained.

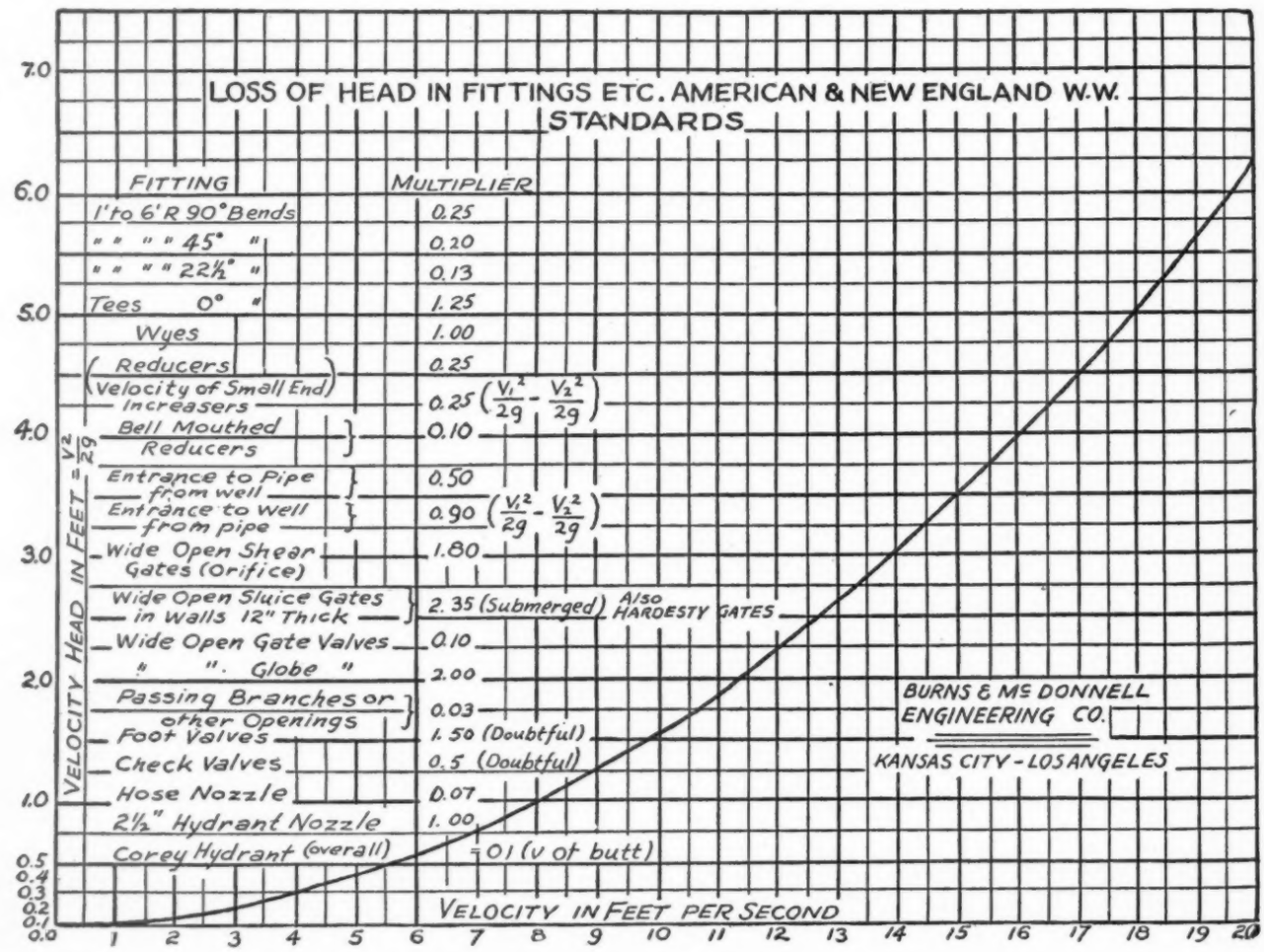
For quick reference the following is suggested: Use a map of the water system mounted on wall board with a push pin to denote the location of each hydrant. The color of the pin can show the condition of the hydrant as reported daily by the hydrant inspectors and the repair foreman. Use a blue pin for a hydrant in good condition, a black pin for a hydrant in need of minor repairs but not out of service, and a red pin for a hydrant out of service. Then when an inspector reports a hydrant out of service it is possible to tell at a glance whether the hydrants around it are in good condition. If several makes of hydrants are in use, it is an advantage to know the make of hydrant before sending out a repair gang so the proper parts can be carried along. By using a small round colored disc under each push pin it is possible to determine at a glance the make of each hydrant, a different color being used for each make of hydrant.

Loss of Head Through Valves and Fittings

(Burns and McDonnell)

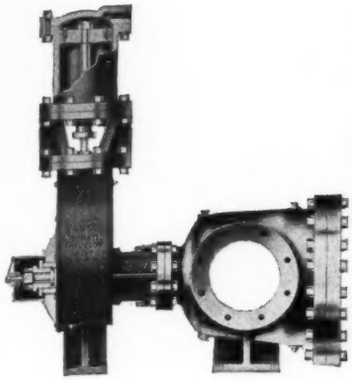
To determine loss of head—Assume flow (Q) to be 5 cu. ft. sec. through a fitting of 12 inch diameter. From Q—AV the velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g} = 0.7$ ft. Applied to 90 degree bend head loss is $0.25 \times 0.7 = 0.18$ ft. For a tee $1.25 \times .7 = 0.87$ ft.

(Note—Recent correspondence with the producers of this chart cites valves for check valves far in excess of the 0.5 indicated.—*Ed.*)


LOSS OF HEAD IN FITTINGS ETC. AMERICAN & NEW ENGLAND W.W. STANDARDS
FITTING
MULTIPLIER
1' to 6' R 90° Bends 0.25
" " " " 45° " 0.20
" " " " 22½° " 0.13
Tees 0° " 1.25
Wyes 1.00
Reducers 0.25
(Velocity of Small End)
Increasers $0.25\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$
Bell Mouthed Reducers 0.10
Entrance to Pipe from well 0.50
Entrance to well from pipe $0.90\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$
Wide Open Shear Gates (Orifice) 1.80
Wide Open Sluice Gates in Walls 12" Thick 2.35 (Submerged)
Also Hardesty Gates
Wide Open Gate Valves 0.10
" " Globe " 2.00
Passing Branches or other Openings 0.03
Foot Valves 1.50 (Doubtful)
Check Valves 0.5 (Doubtful)
Hose Nozzle 0.07
2½" Hydrant Nozzle 1.00
Corey Hydrant (overall) = 0.1 (v of butt)
VELOCITY HEAD IN FEET = $\frac{V^2}{2g}$
VELOCITY IN FEET PER SECOND
BURNS & McDONNELL ENGINEERING CO.
KANSAS CITY - LOS ANGELES

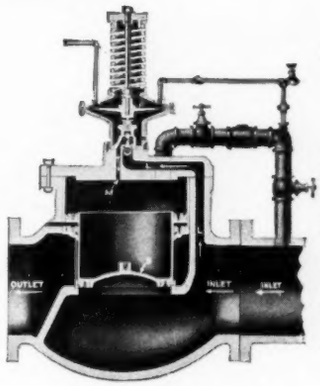
GOLDEN-ANDERSON VALVE SPECIALTY CO.

1350 Fulton Bldg.
PITTSBURGH, PENNA.



THRU-FLOW CONE VALVE

Afford full pipe line flow without friction loss. Always oil lubricated. Axially unseats before it rotates without friction, rub or wear. Especially desirable for sewage disposal service.

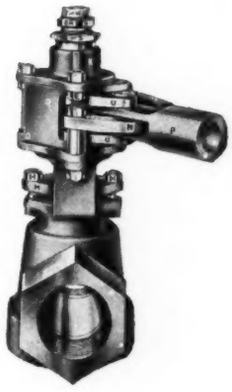


ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24".

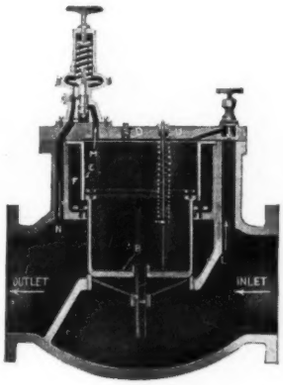
THRU-FLOW PLUG VALVE

Furnished all sizes for lever or handwheel control. Axially unseats and rotates without rub or wear. Easy to operate under hydraulic pressures. Furnished for any liquid services with round port opening.



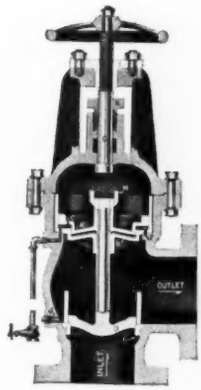
CONTROLLING FLOAT VALVE

Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24".



WATER REDUCING VALVE

Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24".

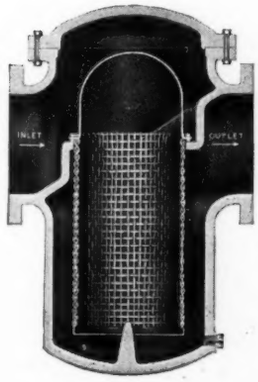


NON-RETURN VALVE

Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12" in angle, globe or elbow patterns.

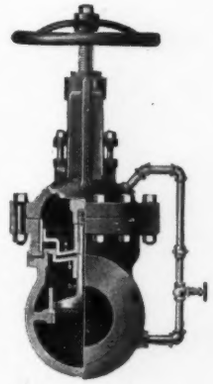
WATER STRAINER

Large capacity with minimum friction loss. Strainer basket quickly accessible and easily cleaned. Basket mesh furnished to suit any service conditions. Sizes to 24".



ENGINE STOP VALVE

The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12" sizes.



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2357 NELSON STREET **CHICAGO, ILLINOIS**

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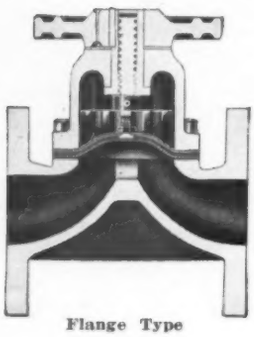
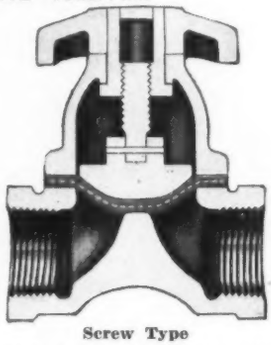


Flange Type



Screw Type

(Made in two types, one for water and compressed air and the other for chemical service).

The construction of this valve is a complete departure from the conventional. There are no metal-to-metal seatings or accurately fitted parts used to effect a tight closure. The materials handled are confined to an area containing no working parts. This liquid area contains no obstructions to catch or lodge suspended matter. Clogging, sticking, leaking or "freezing" of the valve are impossible. The opening and closing medium of the valve is a tough, resilient diaphragm constructed of materials that withstand the service to which valve is put. When closing valve, diaphragm compresses between a follower and a body weir, enveloping any irregularities on weir and forming a perfect leak-proof closure.

Another valuable feature is the two-unit construction. Body of valve is distinctly separate from the bonnet, with the diaphragm in between. This eliminates necessity of removing valve from line for diaphragm replacement. Practically the only repairs necessary are occasional replacement of the diaphragm. The cost is small and diaphragms are changed quickly by merely unscrewing 4 bolts and lifting bonnet from the body.

These valves are in use throughout the world and are the most efficient for any service where high temperatures (above 180°) and high pressures (above 150 lbs.) are not involved. Made in sizes from ½" to 12" with bodies of cast iron lined with lead, rubber or glass, or made of bronzes or stainless steel. Interesting catalog will be sent upon request.

BRASS OR BRONZE ALLOY CASTINGS

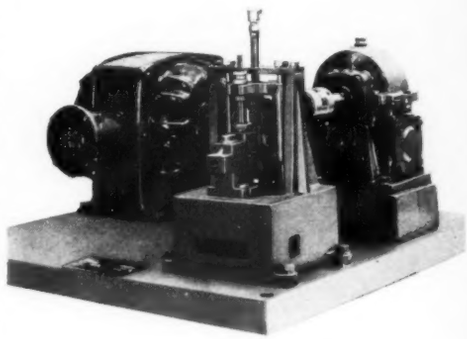
We operate a completely equipped non-ferrous alloy foundry. Production consists of Aluminum Bronze, Manganese Bronze, Monel, Red or Yellow Brass, Gear, Bearing and Pressure Bronze Castings. Our long experience and specialization in the difficult "copper-nickel" and "copper-aluminum-iron" mixes, assures castings free from impurities, of correct physical and chemical structure and absolutely true to blue prints.

Submit your prints for estimates.

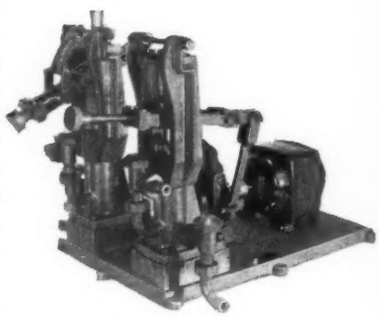
CHEMICAL PROPORTIONING PUMPS

(Made in many sizes, alloys, etc.)

These pumps are designed to provide an exacting mechanical means for feeding and controlling the injection of chemicals, algicides and other treating agents into various processes. Types are available to suit any local power condition, for treating boiler water, feeding coagulants, injecting chlorine, copper sulphate, etc., into water systems, injecting anti-stench liquids into sewage matter, intermixing two different constituents into processes to obtain certain reactions, in fact, for any fluid proportioning problem.



"S" Type High Pressure



"M" Type

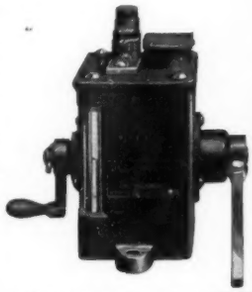
The pumps are ruggedly constructed and employ a single plunger pumping principle with deep packed stuffing boxes and ball, plunger or mechanically-operated valves, whch give them remarkable efficiency and accuracy.

Available for handling volumes ranging from 0 to 6,000 G.P.H., and pressures up to 12,500 lbs.

Send for catalog.

FORCE-FEED LUBRICATORS

Hills-McCanna Force-Feed Lubricators were the first mechanical means devised for oiling stationary or movable equipment, to eliminate the hazards of hand oiling. They are considered the most positive oilers on the market, due to their single plunger pumping principle and other mechanism which assures positive delivery of every drop of oil pumped to bearings and friction surfaces, regardless of any counteracting influences, such as distance pumped, pressure resistance, etc.



Model "ET" — Type "BF"

Made in three types. Drives consist of reciprocating lever, clutch, pulley, sprocket, internal reduction or direct drive, also motor drive through reduction gears. Send for catalog.

HYDRANT DISCHARGE MEASUREMENTS

Practical Methods of Making Measurements; Computing and Applying Results

By P. S. WILSON*
Water Works Consultant, Glen Ridge, N. J.

The measurement of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can authorize for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method, of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.

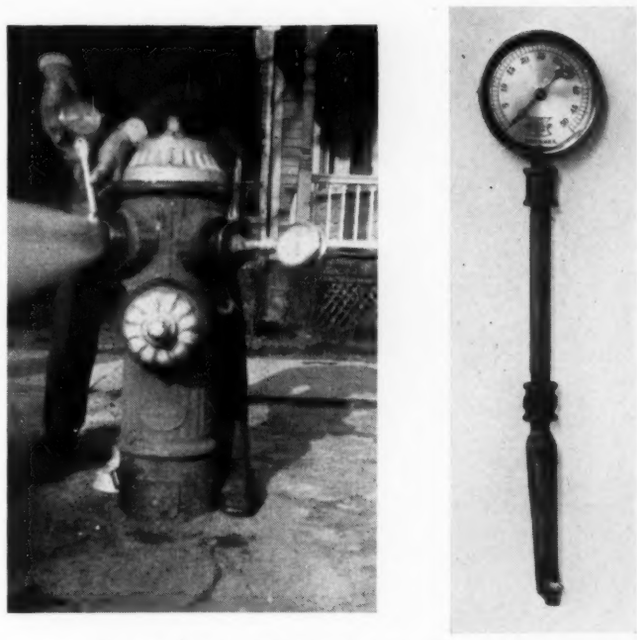
Methods of Measuring Hydrant Discharge

Measurements of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter—Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle used should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.

*Now Technical Asst. Secy., A.W.W.A.



Two Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage, Indicating Barrel Pressure, Show Practically Same Readings)
Hydrant Pitot Tube with Gage at Right

Determining Stream Velocity—The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stream and pointing directly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center will be found to be practically the average. In no case should the pressure very near the edge (within about one-fourth inch) be considered.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barrel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadvantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained the diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14xd^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545xd^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream in feet per second =
$$\sqrt{2.31 \times p} \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =
$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =
$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =
$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =
$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

The Advantage of Tables and Charts

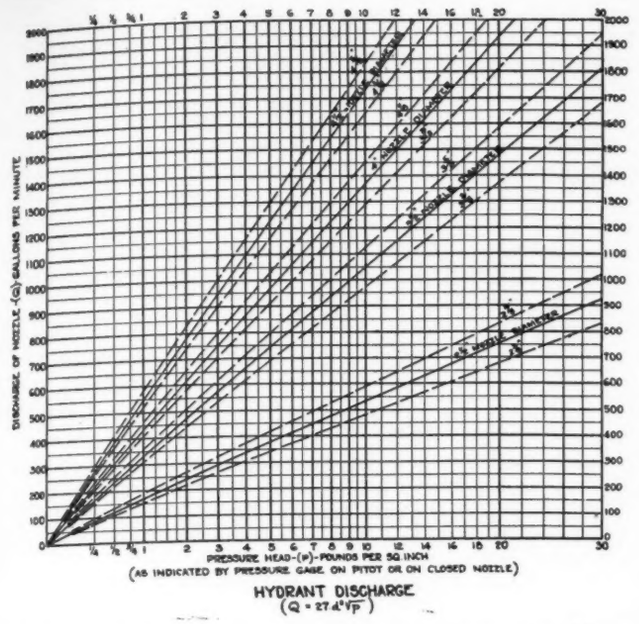
From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1. The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (*d*). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of *d*,—for example 2½ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing ⅛-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the

TABLE 1—HYDRANT DISCHARGE*
Gallons per minute = 27 d² √ p

Gage Reading	Hoze nozzle diameter in inches [d]					
p	2 7/8	2 15/16	2 7/8	2½	2 9/16	2 5/8
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	320	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	460
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	980
30	790	830	880	920	970	1020

*Discharges shown to nearest 10 gals. per min.


DISCHARGE OF NOZZLE (Q)-GALLONS PER MINUTE
PRESSURE HEAD-(P)-POUNDS PER SQ INCH
(AS INDICATED BY PRESSURE GAGE ON PITOT OR ON CLOSED NOZZLE)
HYDRANT DISCHARGE
(Q = 27.4 d²√P)

Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.; this Chart Having Been Prepared by the Author While Connected with the Company)

diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary. Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.

A Few Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this it will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located close by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the discharge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 3280$$ gal. per min. which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1, is the measured discharge with a drop in pressure of D_1; and, Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give

information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

For further details and information regarding fire flow tests the reader is referred to a paper published in the *Journal of the American Water Works Association*, Volume 12, No. 2, October, 1924, by Mr. George W. Booth.

Other Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Acknowledgment—At the request of WATER WORKS AND SEWERAGE, the author has revised and added to an article published by him (Journal of the A. W. W. A. for July, 1930), on the same subject. We believe the practical value of this contribution justifies its re-publication.—*Editor.*

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

Commercial Pipe Sizes for Fire Streams*

Number of 1 1/4-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455
	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	16	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	424	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.

In calculating above table, the following assumptions were made: Nozzles, 1 1/4-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

*Reproduced by courtesy of N. S. Hill, Jr.

ECONOMY OF ELEVATED STORAGE*

By DONALD H. MAXWELL**

The operating records of the Glencoe, Ill., water works furnish a striking demonstration of economy procurable through the introduction of elevated storage. In this case the savings in pumping costs, resulting from use of an elevated tank, are sufficient to cover all annual costs incident to the project.

The Glencoe pumping arrangements and filtration plant were designed to operate in connection with an elevated tank which was omitted in the original construction and the pumps operated against direct main pressures for about 4 years. In 1932, a 500,000 gallon elevated tank was added and now records under the new conditions are available to show a saving of about 33 per cent in power consumption.

The Glencoe filter plant has two motor driven low lift pumps each of two million gallons rated capacity and three motor driven high lift pumps, of one, two and four million gallons rated capacity respectively. In addition there is gasoline engine driven standby equipment. The average daily pumpage is approximately one million gallons, the rates varying from a minimum of approximately 420,000 g.p.d. to a maximum of 3,300,000 g.p.d. The maximum hourly rate of consumption is approximately 5,200,000 g.p.d. and the minimum hourly rate is about 300,000 g.p.d.

Pumping Conditions With and Without Elevated Tank on the System

Comparison of these consumption rates with the installed pump capacities makes it evident that the high lift pumping operating against direct main pressures, with pumps throttled a considerable part of the time, was necessarily inefficient. The low lift pumping was also inefficient, owing to the desirability of maintaining a full clearwell and thus a 500,000 gallons storage. To do this it was the practice to operate the filters more or less continuously with the low lift pumps throttled. At times these pumps had to be operated at 15 per cent of rated capacity.

With the elevated tank in service the high lift pumps now operate intermittently at about their rated capacity and best efficiency. With present practice, maintaining the clearwell storage at not less than 75 per cent full, is accomplished by running one or two low lift pumps which operate at about rated capacity during approximately the same periods as the high lift pumps are in service.

Improved Pressures

The pressures maintanied in the business district when pumping against main pressures varied over an extreme range of 40 pounds per square inch. The variation was from approximately 28 pounds minimum to 70 pounds maximum. Under present conditions, with the tank in service, a very uniform pressure is maintained, having an extreme range not to exceed 20 pounds. From 35 pounds minimum to 55 pounds maximum is recorded at the business center. The changed pressure conditions are clearly shown on the pressure charts, revealing recording gage pressures before and after providing elevated storage.

Savings in Power Consumed

As now operated the pumps run at capacity from 4 to 24 hours a day depending on the season, whereas formerly they ran continuously during periods of light as well as heavy demands. Much of the time they were throttled thus producing a very considerable sacrifice in efficiency as becomes apparent by comparing the power consumption with and without elevated storage, as shown in Table I.

During 1931 (operating direct pressure) the power consumption averaged 1,835 k.w. hours per million gallons delivered to the mains. During the six months of operation with the elevated tank in service, the power consumption per million gallons

500,000 *Gallon Elevated Tank, Glencoe, Ill.*

TABLE I—PUMPAGE AND POWER DATA COMPARING OPERATION WITHOUT AND WITH ELEVATED TANK, GLENCOE, ILLINOIS WATER WORKS

Month	Pumpage, million gallons	Kw.hrs. per calendar month	Kw.hrs. per m.g.d.	Kw. max. demand
1931 (without tank)				
January	21.467	47,600	2,220	87
February	17.568	40,000	2,280	78
March	20.265	45,600	2,250	81
April	22.877	47,400	2,070	126
May	29.097	55,200	1,900	174
June	37.153	60,400	1,620	192
July	55.516	80,800	1,450	249
August	56.960	79,600	1,400	246
September	34.030	62,000	1,820	174
October	27.580	59,000	2,140	114
November	23.116	50,000	2,160	102
December	22.362	47,800	2,140	99
Total or average	367,991	675,400	1,835*	
1932 (only those months with new tank in service throughout month)				
March	21.578	27,400	1,270	117
July	45.083	55,200	1,225	186
August	46.437	56,800	1,225	189
September	38.920	47,200	1,210	168
October	23.700	29,600	1,250	174
November	19.502	25,000	1,280	120
Total or average	195,220	241,200	1,235*	

*Weighted average.

(*Continued on page* 206)

*Excerpts from an article which appeared in Water Works and Sewerage.

**Of Alvord, Burdick & Howson, Consulting Engineers, Chicago.

CHICAGO BRIDGE

Chicago.....2198 Old Colony Bldg.
New York.3390-165 Broadway Bldg.
Cleveland...2262 Rockefeller Bldg.
Dallas....1479 Liberty Bank Bldg.
Birmingham....1586 North 50th St.
Tulsa.....1646 Hunt Bldg.

Plants in CHICAGO, ILL.; BIRMINGHAM, ALA., and GREENVILLE, PA.

PRODUCTS

BINS, Storage
BREECHINGS, Steel
CHUTES, Steel
FILTER PLANTS
FLUMES, Iron and Steel
GASHOLDERS, High and Low Pressure
HOPPERS, Steel
PENSTOCKS
PIPE, Riveted steel
PIPE, Welded steel
PRESSURE TANKS, Welded and Annealed
RESERVOIRS, Steel
RECEIVERS, Air
SMOKE STACKS
STANDPIPES
STEEL PLATE CONSTRUCTION
TANKS, Elevated Steel.
TANKS, Storage
TANKS, Surge
TANKS, Washwater

FACILITIES

We are equipped to design, fabricate and erect all types of steel plate work, riveted or welded. No work too special. When requesting estimating figures on tanks, state capacity, height to bottom for elevated tanks, and describe location.

INFORMATION

We are glad to supply municipal officials and waterworks engineers with information or estimating figures. Write our nearest office. There is no obligation on your part.

250,000-gal. Horton ellipsoidal-bottom tank at Brawley, Calif. The tower is specially designed and has double rods to withstand earth shocks.

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

This type of tank is built in a complete range of standard sizes as shown in the accompanying table. The diameter of the tank is relatively large and the depth shallow, reducing the variation in pressure between the upper and lower water levels. The proportions of this design are also well balanced, presenting a pleasing appearance. (See illustration at upper left.)

Ellipsoidal - bottom tanks are equipped with large steel risers riveted directly to the bottom of the tank. The size of the riser varies from three to six feet, the larger sizes being used in northern climates to prevent freezing. State capacity, height to bottom and location when requesting prices.

ELLIPSOIDAL-BOTTOM TANK SIZES

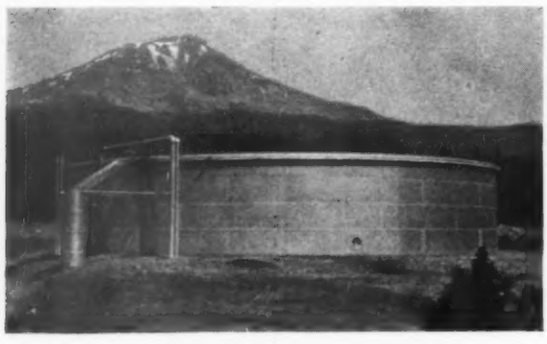
Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20'0"	13'9"	5'0"	18'9"
50,000	22'0"	14'0"	5'6"	19'6"
60,000	24'0"	14'0"	6'0"	20'0"
75,000	26'0"	15'0"	6'6"	21'6"
100,000	28'8"	16'0"	7'2"	23'2"
125,000	28'8"	21'2"	7'2"	28'4"
150,000	34'0"	16'6"	8'6"	25'0"
200,000	38'0"	17'6"	9'6"	27'0"
250,000	40'0"	20'0"	10'0"	30'0"
300,000	41'0"	23'9"	10'3"	34'0"
400,000	47'0"	23'2"	11'9"	34'11"
500,000	51'0"	24'3"	12'9"	37'0"
600,000	54'0"	26'3"	13'6"	39'9"
750,000	54'0"	32'0"	18'0"	50'0"
1,000,000	60'0"	34'0"	20'0"	54'0"
2,000,000	80'0"	35'6"	26'0"	61'6"

Height to bottom—any even foot.

125,000-gal. washwater tank at filtration plant, New Milford, N. J. It is of radial-cone bottom design.

RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design was developed to permit the construction of large capacity tanks with a small range in head. Radial-cone tanks are



104-ft. dia. steel water reservoir serving McCloud Calif. The tank is located on a hill 190 ft. above the town.

Here are two 5,000,000 g.p.d. Morse Filter Plant units at Burnt Mills, Md.

& IRON COMPANY

Houston.....2919 Main St. Boston.1548 Consolidated Gas Bldg.
Detroit.....1551 Lafayette Bldg. San Francisco....1083 Rialto Bldg.
Philadelphia..1644-1700 Walnut St. Los Angeles...1455 Wm. Fox Bldg.

In Canada: HORTON STEEL WORKS, Ltd., Ft. Erie, Ontario

of sound structural design. They present a pleasing appearance. Construction details such as tower bracing, hand railing, etc., may be varied to secure the desired architectural effect. The accompanying table indicates the proportions for various capacities.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61′	25′
750,000	76′ 8″	25′
1,000,000	87′	25′
1,500,000	106′	25′
2,000,000	122′	25′

THE MORSE FILTER PLANT

The Morse filter plant is a rapid sand type plant. It is built entirely of steel in convenient sized units. The filters, coagulating basins and reservoirs are located in concentric circles, providing a compact arrangement. A 5 m.g.d. unit covers a circle 100 ft. in diameter. The advantages are summarized as follows:

1. All-steel construction offers the same advantages that have proved so desirable in large capacity water storage tanks. No seepage, no cracking, less maintenance expense.
2. 30 to 40 per cent lower in first cost with all things being equal. Also requires less ground space per unit of capacity than any other type of construction.
3. Modern. Definitely designed to push obsolescence as far into the future as possible.
4. Flexible in both operation and application. Put in capacity needed at present; add more capacity easily and economically at any time in future.
5. Lower operating costs. Very small loss of head through plant means less pumping cost. Cleaning and maintenance is easier and quicker.

WASHWATER TANKS

We build ellipsoidal, radial-cone or special shaped tanks to give exactly the capacity, head, and pressure variation required for washing filters. They are more dependable and economical than direct pressure washing.

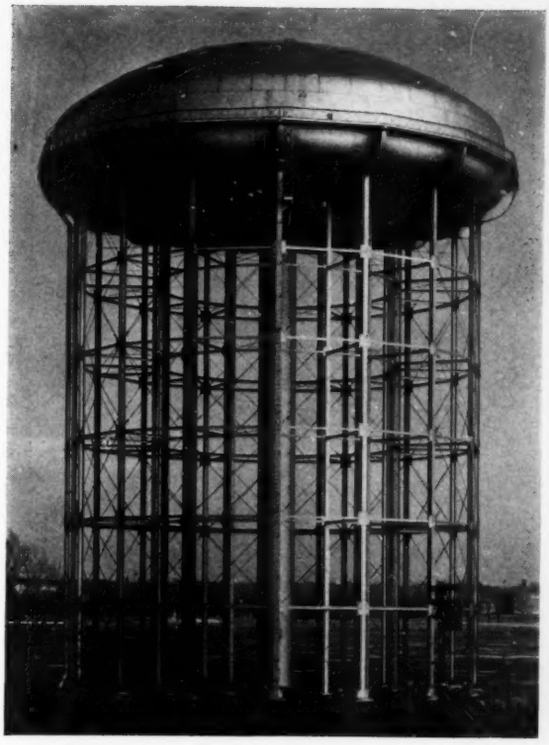
RESERVOIRS

Where natural elevations are available, steel reservoirs provide gravity pressure. They are built in standard sizes or special designs to meet your requirements, of riveted or welded construction, with or without roofs.

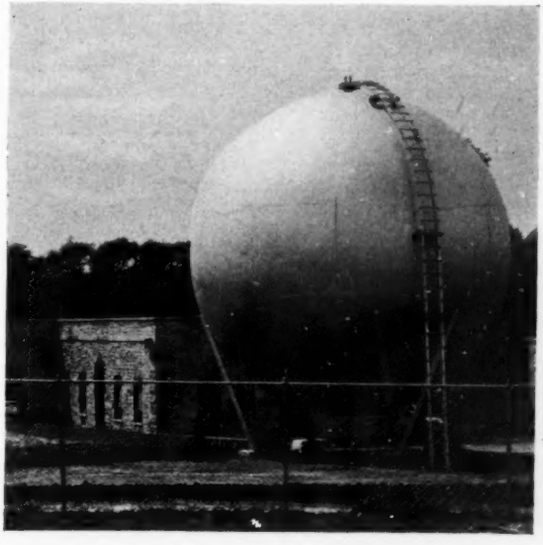
SEWERAGE GAS HOLDERS

When gas from digesters at sewerage disposal plants is utilized, excess quantities produced during peak periods can be stored advantageously under pressure in a Hortonsphere for use during off-peak periods. Hortonspheres are relatively small in size and pleasing in appearance. We also build conventional water-lift gas holders.

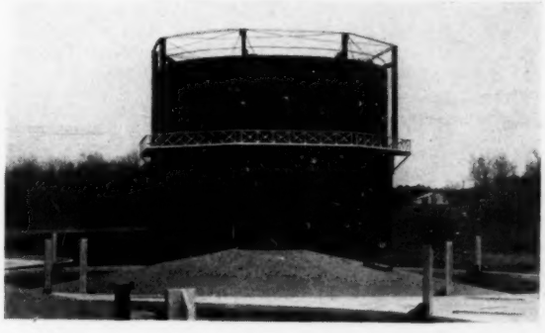
This 1,250,000 g.p.d. Morse Filter plant is located near Lorton, Virginia.



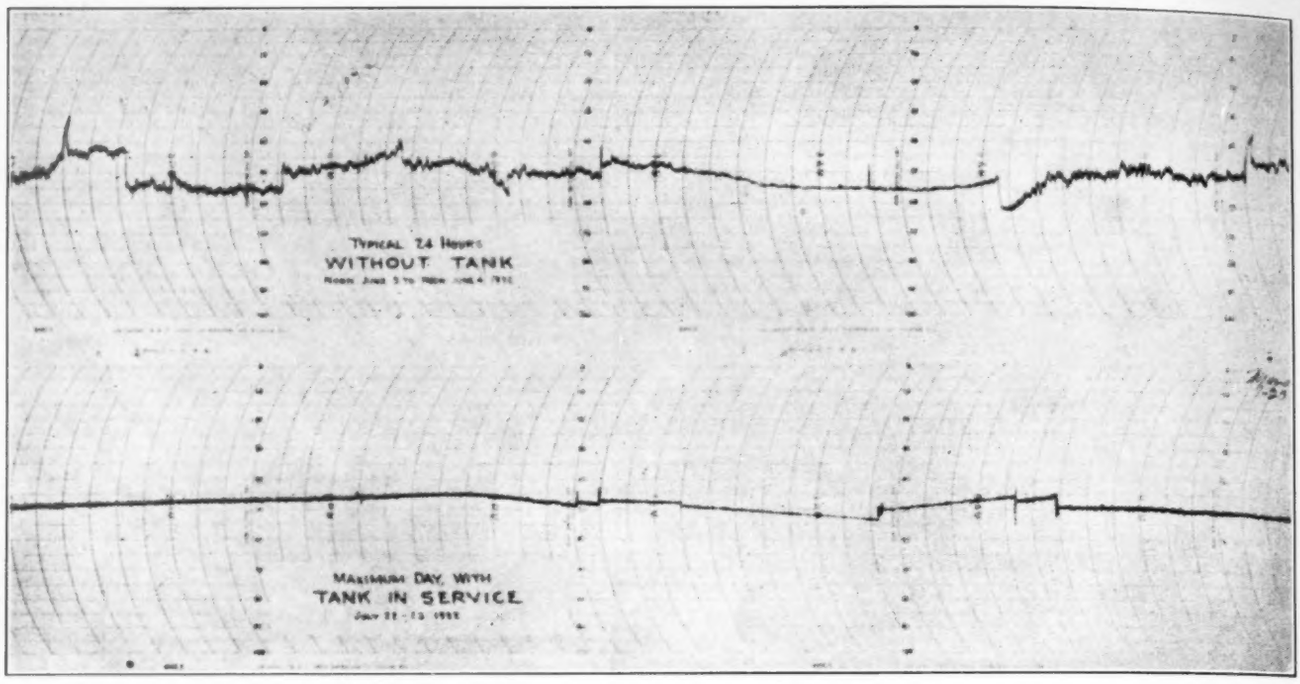
Here is one of the three 2,000,000-gal. Horton radial-cone bottom tanks that have been placed in service recently in the Buffalo, N. Y., waterworks system.



Hortonsphere used to store sewage gas at 40 lbs. per sq. in. pressure at Beaver Dam, Wisconsin.



50,000 cu. ft. welded steel holder for gas produced from activated sludge at sewage treatment plant, Durham, N. C.



Record Gage Pressures Before and After Elevated Storage Was in Service

pumped has averaged only 1,235 k.w. hours, almost exactly two-thirds of the former power use and much more uniform as shown by the tabulation.

The saving in cost of power due to improved operation, made possible by the tank, cannot be properly shown by direct comparison of power bills for corresponding periods under the old and the new conditions because of the fact that a new power rate was introduced some time after the elevated tank went into service, and also because there has been a decrease in pumpage approximating ten per cent.

The fairest estimate of saving in power cost is obtained by applying the new power rate to the recorded 1931 pumpage as it actually occurred for comparison against the same monthly pumpage if delivered under more efficient operation as now attained with elevated storage. The saving calculated in this manner, amounting to approximately $2,500 a year, is sufficient to cover interest on the investment, depreciation (on sinking fund basis) and maintenance of the tank.

Thus, without added annual cost, the village has been able to avail itself of the many advantages of elevated storage which includes doubling of reserve storage, better fire protection, uninterrupted and more uniform water pressure, greater flexibility of filter and pumping operations and increased plant reliability.

It is worth noting that the saving in cost of power would have been greater if Glencoe had happened to enjoy a uniform rate of power, such as applies in many plants. In reducing the power consumption by 33 per cent the plant is not able to earn proportionately as good a rate. The estimated net average power cost based on the new rate when applied as above explained to 1931 pumpage without the tank nets 1.27c per kw.h., whereas with the tank it is increased to 1.36c per kw.h.

Auxiliary Equipment

The elevated tank is equipped with an altitude valve and a remote indicating water level gage is installed in the pumping station 2⅓ miles away to make practicable the full use of the storage capacity available.

The elevated tank was supplied by the Chicago Bridge & Iron Works. The Glencoe plant is in charge of E. L. Pflanz, Superintendent, and George R. Young is Village Manager.

Old Standpipe Rehabilitated by Guniting

By V. VON GEMMINGEN

Town Manager, Culpeper, Va.

During the year 1895 the town authorities of Culpeper, Va., erected a standpipe of 300,000 gals. capacity. During its 38 years of service it had gotten into such a weakened condition from corrosion that for a time it appeared as if it would have to be replaced by a new tank or reservoir and, thereafter, removed at an expense in addition to the expense incurred in providing new service storage.

After giving some study to the matter of possible renovation of this old structure, by application of a jacket of cement mortar from a gun—"Guniting"—it was estimated that the project would cost $4,000 or thereabouts. There was a large difference between that figure and the estimated $18,000 or more which it would have cost to provide a new tank or reservoir. It was decided to proceed with the project of Guniting the standpipe and its base.

First, the town laid a heavy false bottom in the standpipe consisting of a reinforced concrete slab. The contractor* came in and cleaned the inside walls of the structure and welded the necessary reinforcing and holding wires to its sides. "Gunite" was then applied, starting with a thickness of 2.5 inches at the bottom and running out to 1.5 inches at the top. On top of this a second or "seal-coat" was applied and in *three* days water was turned back into the standpipe.

The structure has shown no signs of leakage, whereas, prior to its renovation, there were approximately 50 active leaks in the side walls, and in one spot a hole about half the diameter of a lead pencil had been eaten through the iron plate.

The standpipe rests on a rubble masonry base from which much of the cement mortar had disintegrated. This unsightly, and probably dangerous, foundation structure was also "Gunited" to produce a sightly and strong structure.

The 39 year old standpipe, which a year ago was ready to be junked as worthless, is today as serviceable as when new and apparently good for another 30 years if not longer. We feel that we have made an excellent investment in having spent $4,000 and thereby avoided an expenditure of at least $18,000—a net saving of $14,000. The "Guniting" job has been in every respect satisfactory and we are highly pleased with the results.

*The work was done by the National Gunnite Co.

PITTSBURGH-DES MOINES STEEL COMPANY

Tanks—Plate fabrication—Structural Steel

P·DM

SALES OFFICES AT

3418 Neville Island, Pittsburgh, Pa.
919 Tuttle Street, Des Moines, Iowa
Room 918, 270 Broadway, New York
1222 First National Bank Bldg., Chicago, Ill.
1223 Praetorian Bldg., Dallas, Tex.
625 Rialto Bldg., San Francisco, Calif.

In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I.—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks

Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	... ..	... ..	... ..	... ..
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	... ..	... ..	... ..	... ..
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	... ..	... ..	... ..	... ..
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	... ..	... ..	... ..	... ..
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.. ..	94 8	100 0	... ..	125 0	... ..	... ..	... ..	... ..	... ..
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.. ..	94 8	100 0	... ..	125 0	... ..	... ..	... ..	... ..	... ..
40,000	17	18 5	25 1	46 8	.. ..	.. ..	75 0	.. ..	96 3	100 0	... ..	125 0	... ..	... ..	... ..	... ..	... ..
50,000	19	17 7	25 7	.. ..	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4		
60,000	19	22 6	30 6	.. ..	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4		
75,000	21	22 6	30 6	.. ..	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4		
100,000	24	22 6	31 0	.. ..	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4		
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 6	140 3	148 7		
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2		
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0		
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1		
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8		
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7		
600,000	44	38 6	58 2	Tower heights have not been standardized for these capacities and can, therefore, be built to suit the requirements in each particular case.													
750,000	50	34 9	57 5														
1,000,000	50	52 0	73 9														

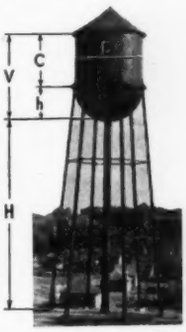
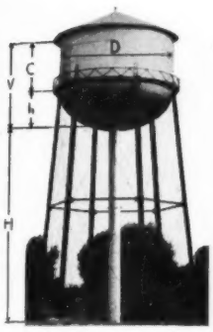


Table II.—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Elevated Tanks



Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.. ..	96 4	100 0	... ..	126 8	... ..	... ..	... ..	... ..
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.. ..	96 1	100 0	... ..	126 5	... ..	... ..	... ..	... ..
40,000	21	11 3	16 9	47 5	.. ..	.. ..	75 0	.. ..	97 5	100 0	... ..	126 2	... ..	... ..	... ..	... ..
50,000	22	13 2	19 0	.. ..	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6	
60,000	24	12 10	19 4	.. ..	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10	
75,000	26	13 6	20 8	.. ..	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2	
100,000	28	16 2	23 2	.. ..	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10	
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10	
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4	
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1	
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 1	
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0	
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 0	129 4	146 0	152 5	
600,000	55	21 9	39 7	Tower heights have not been standardized for these capacities and can, therefore, be built to suit the requirements in each particular case.												
750,000	60	22 4	42 4													
1,000,000	60	35 0	54 0													
1,000,000	65	26 1	47 7													
1,250,000	79	17 4	43 4													
1,500,000	70	37 8	60 0													
1,500,000	79	24 0	50 0													
2,000,000	90¼	22 6	50 0													

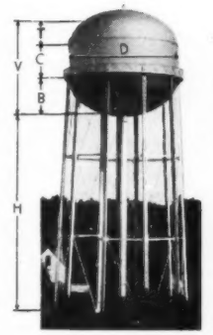


Table III.—Double Ellipsoidal Tanks

Capacity in U. S. Gallons	Tanks D ft.	V ft. in.	H
100,000	28	23 8	
150,000	34	26 9	
200,000	38	27 7	
250,000	38	33 7	Built
275,000	40	33 2	to
300,000	42	31 7	Order
350,000	44	36 6	
400,000	46	35 7	
500,000	50	39 2	
600,000	54	40 0	
750,000	Dimensions on request		
1,000,000			

Table IV.—Railroad Type Tanks

Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H
20,000	15	10 9	16 2	Any
25,000	15	14 7	19 11	height
30,000	17	12 7	19 0	from
40,000	19	13 1	20 6	15'0"
50,000	21	13 1	21 1	to
60,000	24	10 1	20 3	40'0"
75,000	24	15 1	23 10	in
100,000	28	13 5	23 7	multi-
150,000	28	24 2	34 7	ples
200,000	36	15 1	29 2	of
250,000	38	17 3	33 3	5'0"
300,000	38	23 11	38 3	

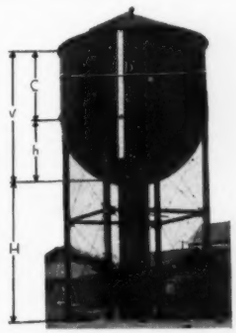
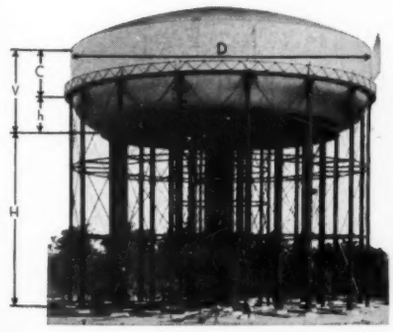


Table V.—Toroidal Bottom Tanks



Capacity in U. S. Gallons	Tank Diameter (D) when h = 10'0" and V=20'0" ft. in.	V=25'0" ft. in.	V=30'0" ft. in.	V=35'0" ft. in.	H
750,000	82 0	73 2	66 8	61 8	
1,000,000	94 5	84 3	76 9	71 0	
1,250,000	105 4	94 0	85 8	79 2	
1,500,000	115 2	102 9	93 9	86 8	Built
2,000,000	132 8	118 5	108 0	99 11	to
2,500,000	148 0	132 3	120 7	111 6	Order
3,000,000	162 0	144 8	131 11	122 1	
4,000,000	186 8	166 9	152 2	140 9	
5,000,000	208 6	186 3	169 11	157 3	

Table VI.—Steel Reservoirs

Capacity in U. S. Gallons	Diameter ft.	Height ft. in.
50,000	24	15 1
75,000	24	22 7
100,000	30	19 3
125,000	30	24 0
150,000	36	20 1
175,000	36	23 4
200,000	36	26 8
300,000	42	29 4
400,000	42	39 1
500,000	48	37 5
600,000	60	28 10
750,000	72	25 0
1,000,000	84	24 6
1,500,000	96	28 1
2,000,000	120	24 0
2,500,000	132	24 10
3,000,000	144	25 0
4,000,000	168	24 6

PIPE LINE FRICTION COEFFICIENTS

A Summary of the Findings of the Committee on Pipe Line Friction Coefficients*

The voluminous report embracing data collected and compiled by the above committee has been printed in the September, 1935, *Journal* of the New England Water Works Association, and is available in the form of reprints.

A summary of the scope of this report and the conclusions presented therein are reviewed in the following abstract, prepared by E. T. Killam, chairman of the Committee.

The general conclusions drawn from the data submitted to the Committee are as follows:

1. The average *actual* loss in capacity of tar-coated cast-iron pipe after 30 years of service, based on a total of 473 tests in 19 different systems, was 52 per cent.

The loss *predicted* in the Williams-Hazen tables for mains of similar age and diameter (average 20.5 in.) and for "average soft unfiltered river water" is 32.3 per cent.

2. Based upon the data available to the Committee, the Williams-Hazen age-coefficient relation is applicable primarily to large-diameter mains carrying relatively inactive water.

3. For small-diameter mains carrying active water, the actual *loss* after 30 years may be twice the Williams-Hazen *predicted* loss.

4. Other factors being equal the data show marked correlation between pH value of water carried and rate of capacity loss, average conditions reported indicating for supplies with a pH value of 6.5, twice the loss observed in supplies with a pH value of 8.0.

Scope of Report

The principal objective of the report was the presentation of heretofore unpublished data upon friction coefficients of tar-coated cast iron pipe, with particular reference to the age-coefficient relation for this type of pipe, and the effect of water quality upon rate of capacity loss.

The report also contains sections dealing with various remedial measures for reducing and preventing loss of capacity, including discussions of coefficients of cement and bitumastic-enamel linings; methods of lining pipe in place; corrective treatment of the water carried, and pipe cleaning.

Certain other subjects not involved in the question of discharge coefficients of tar-coated cast-iron pipe, but falling within the general scope of the subject of "Pipe Line Friction Coefficients," have been presented in the form of appendices, in order that this additional information might be made readily available in a single report.

Precision

The Committee has endeavored to compile mass data of reasonable precision; obviously, the widely varying conditions found, and the many factors involved, could not be generalized upon any other basis. Accordingly, while the collection of data was in no way restricted to sources affording "laboratory" precision, the material presented includes only such data as have been considered to fall within the limits of reasonable precision set by the Committee.

This policy of precision applies particularly to the presentation of various "trend curves," which is the designation adopted for expressing the age-coefficient relation. These "trend curves" in which values of C have been plotted against the age of the pipe in years, have been presented only in cases for which numerous tests of reasonable accuracy were available.

In considering these trend curves it should be emphasized that the results represent actual field tests and accordingly include all incidental losses due to irregular line or grade, and due to fittings or special castings.

Use of Williams-Hazen Coefficient "C"

The Williams-Hazen formula has been used throughout the report for the determination of coefficient values, and all values of C refer to the Williams-Hazen coefficient in the following formula:

$$v = C\ r^{0.63}\ s^{0.54}\ 0.001^{-0.04}$$

v = Velocity in feet per second
r = Hydraulic Radius in feet
s = Hydraulic slope in feet per foot
C = The Williams-Hazen Coefficient

In translating values of C to equivalent capacity loss, it is convenient to bear in mind that capacity is directly proportionate to the value of C. With slope and diameter fixed, a drop in the value of C from 130 to 65 consequently involves an equivalent capacity loss of 50 per cent.

Coefficients of Tar-Coated C. I. Pipe

Tar-coated cast iron pipe has been more widely used in water works practice than any other type of pipe, and a discussion of coefficient values with this type of pipe was accordingly selected for the first and principal subject of the report.

In considering the existing condition of old pipe, and attempting to determine the loss of capacity with age, selection of a value of C for new pipe becomes a fundamentally important assumption. The values of C for new tar-coated cast iron pipe adopted in the report are as follows:

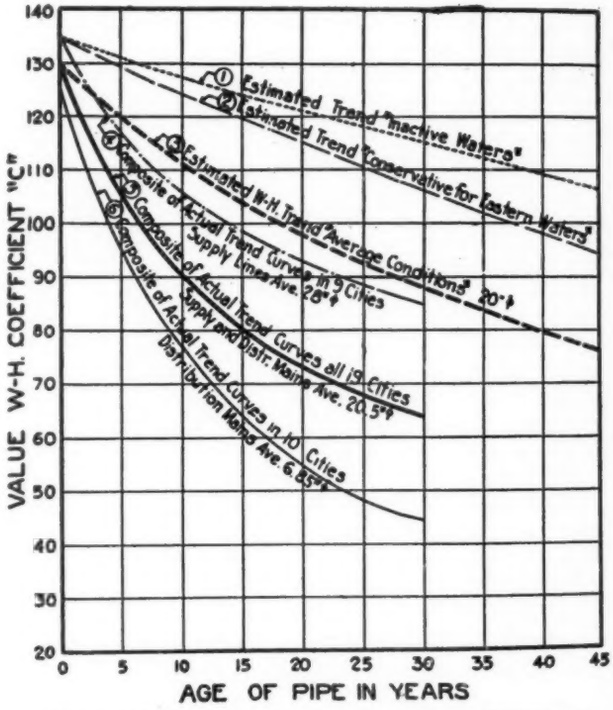


Fig. 1.— Summary of Estimated and Actual Trends of Age-Coefficient Relation for Tar-Coated Cast-Iron Pipe.

***Curves* 1 *and* 2 are based on data for steel pipe (U. S. Dept. of Agriculture, Bull. 150, 1930).**

***Curve* 3 is based on the Williams-Hazen Tables for average soft unfiltered river water.**

***Curve* 4 is a composite for supply and transmission lines 16 in. or larger in diameter.**

***Curve* 6 is a composite for distribution mains less than 16 in. in diameter.**

***Curve* 5 is a composite of Curves 4 and 6. Composite curves are based on arithmetic averages.**

Actual vs. Estimated Losses in Main Capacities with Age Increase Summary Curves Taken from the Report of the Committee of N. E. W. W. A. on Pipe Line Coefficients

*Presented before the New England Water Works Association September 17, 1935.

For supply and transmission mains 16 inch and larger in diameter ..... C = 135
For distribution mains less than 16 inch in diameter, with allowance for Ts, valves, bends, corporation cocks, or other specials involving friction loss..... C = 125

Variations possibly approaching 10 per cent higher or lower may be found, but the foregoing represent the average values from data available to the Committee.

The most widely used basis for estimating the probable loss of capacity of tar-coated cast iron pipe with age, (other than the convenient, though inadequate, assumption that C = 100) is the age-coefficient relation shown in the column headings of the Williams-Hazen tables.

These Williams-Hazen predicted age coefficient relations—or trends of C—accordingly form a convenient basis for comparison with actual trends computed from the data submitted to the Committee.

The data compiled on actual trends of the age-coefficient relation for tar-coated C. I. pipe includes a total of 473 tests in 19 different cities. These data, results of which have not heretofore been published, have been classified and are presented in the form of trend curves.

These trend curves, as in the assumption of values for new pipe, have been segregated into two major classifications, namely, for supply and transmission mains 16-inch and over in diameter, and for distribution mains less than 16-inch in diameter.

Further classification has been made by grouping trend curves of similar type or source of supply; or according to general location or type of supply.

Summary of Data on Actual Capacity Loss in Tar-Coated C. I. Pipe

The data on actual loss of capacity in tar-coated C. I. mains may be briefly summarized, as follows:

Supply lines in nine cities showed a loss after 30 years of 37 per cent as compared with a predicted Williams-Hazen loss of 30 8 per cent.

Distribution mains in ten cities showed an actual loss in 30 years of 64 per cent as compared with a Williams-Hazen predicted loss of only 37 per cent.

Average results of 473 tests in 19 individual systems, including sizes ranging generally from 6-inch to 48-inch in diameter, with a weighted average size (according to numbers of tests of each size) of 20.5 inches, showed an actual loss in 30 years of 51.5 per cent, as compared with a predicted loss of 32.3 per cent for pipe of the same diameter.

These data accordingly indicate that the Williams-Hazen predicted trends are applicable primarily to large diameter mains carrying relatively inactive water—and do not represent "average conditions."

Quality of Supply and Its Effect on Capacity Loss

The wide variation in rate of capacity loss in different systems and the appreciable extent to which this loss progresses in a relatively short time in many systems, directs attention to probable causes of such loss. In collecting data, the Committee has accordingly attempted to consider the quality of supply and its effect upon rate of capacity loss.

Alkalinity and carbon dioxide have an important effect on rate of capacity loss. Because of the inter-relation between alkalinity, carbon dioxide, and pH, this effect may be measured against the pH value alone.

The relation of pH to rate of capacity loss has been illustrated in the report by a diagram on which the per cent of capacity loss in a fixed period, (30 years) in various supplies, has been plotted directly against the pH of the supply.

The pronounced relation indicated by the data, showing the marked effect of pH on the relative rate of loss, may be summarized as follows:

pH Value of Supply	Approximate Average Per Cent Capacity Loss in Tar-Coated C. I. Pipe (In 30 Years)
8.0	30
7.5	35
7.0	45
6.5	60
6.0	85

Capacity Loss in Tar-Coated C. I. Pipe Due to Special Causes Other Than Tuberculation

Although tuberculation is most frequently the cause of loss of capacity in tar-coated cast iron mains, certain cases included in the Committee data afford examples of capacity loss due to other special causes. In some instances the resulting trends of capacity loss are quite similar to cases where loss was caused by tuberculation. Among special causes of capacity loss are: incrustation, due to the precipitation on the pipe either of natural mineral content in the water, or of lime after water treatment; slime or fungus growth; and silting.

Coefficient Values of Cement-Lined Pipe

In addition to the main section of the report dealing with friction coefficients of tar-coated cast iron pipe, a number of related subjects involved in the general question of friction coefficients, are discussed.

Accordingly a second section of the report is devoted to coefficient values of cement-lined pipe.

The development of the centrifugal method of applying cement lining has inevitably resulted in the increased use of this type of lining as a method of preventing capacity loss. Available data upon the values of C for cement-lined pipe are limited in scope and widely scattered in the literature. Accordingly, all available data have been compiled and presented in order that they may be made more readily available.

The Committee data indicates that the average value of C for new pipe, 4-inch to 24-inch in diameter with cement lining centrifugally applied, is 134, based on nominal diameter; and 150 based on actual net diameter.

These data also indicate that at least for mains 24-inch or less in diameter, the effect of lining thickness on diameter encroachment is sufficient to warrant considering values of C based both on nominal and on actual net diameter.

Other tests on pipe with cement linings not applied by centrifugal methods showed the following values: For pipe with natural or Rosendale cement lining tested both when new and at the end of approximately a 10-year period, C = 136; for old style cement lined wrought-iron pipe 12-inch and 14-inch diameter, after 41 years of service, C = 104.

Available data relative to the value of cement lining in maintaining hydraulic capacity are extremely limited in scope. One line tested when new and again after six years of service showed no loss of capacity. Another line tested when new and after 1, 7, and 10 years of service, also showed no tendency to decrease in carrying capacity with age. The data indicate that cement lining can be credited with a sustained capacity not attainable with tar-coating.

Coefficient Values of Pipe with Bitumastic Enamel Lining Centrifugally Applied

A third section of the report is devoted to a discussion of coefficient values with Bitumastic enamel lining applied by the centrifugal method. As in the case of cement lining, development of centrifugal methods of application have resulted in a greatly increased use of this type of lining to control capacity loss. Due to limited data available, results of all of the tests which have been conducted, together with a discussion of test methods, have been presented in the report. Results available include tests on 10, 12, and 20-inch cast iron pipe; and on 30-inch steel pipe.

The data indicate that coefficient values for new supply and transmission mains 16-inch in diameter and larger, with bitumastic enamel lining (centrifugally applied) may vary from C = 145 to C = 160 with an average value of C = 155; all based on nominal diameter.

These data also indicate that coefficient values for distribution mains less than 16-inch in diameter, with this style of lining, may vary from C = 140 to C = 150 with an average value of C = 145.

Bitumastic enamel lining is ordinarily applied with a thickness of only 3/32-inch. Encroachment on diameter is accordingly small, as compared with other types of lining.

The first application of this type of lining was in 1931, and accordingly no data is available relative to its effectiveness in sustaining hydraulic capacity. The longest service period reported is two years, and the results of this test indicate no loss. The same material applied by the hand-brush method has been widely used for many years, and visual inspection of large pipe thus lined indicates that at least within periods of 16 years no apparent deterioration has occurred.

Application of Linings to Mains in Place

While the foregoing methods of lining pipe provide methods of preventing or retarding capacity loss on new work, the question of restoration of capacity of many miles of mains already in place is of no less importance. The high cost of

abandonment and duplication of existing mains, particularly under permanent pavements has directed attention to possible methods of reconditioning or lining existing mains in place, subsequent to cleaning.

Reference is made in one section of the report to available methods of lining mains in place.

Two methods have been devised in England for lining small diameter mains; the "Eric" process by which a bitumen lining is deposited electrically; and the Tate process, by which a cement-mortar lining is deposited in the pipe.

In this country, two methods have been developed for the reconditioning and lining of large diameter mains. On pipe lines sufficiently large to permit entry, the lines may be carefully cleaned and then treated with an application of hot bitumastic lining. A second method, which has recently been developed, involves the centrifugal application of a cement lining to large diameter mains in place. The lining is whirled into place by centrifugal force from a high speed centrifugal jet.

Corrective Treatment

In addition to the use of protective linings, chemical treatment of the water for reduction of corrosion has been adopted in recent years to abate the problem of capacity loss, and mention is made in the report, of some of the more important phases of corrective treatment.

Lime, sodium hydroxide and soda ash are among the alkalies used to reduce corrosion.

If water is maintained saturated with respect to calcium carbonate, it will be practically non-corrosive to iron.

In maintaining adequate corrective treatment it is essential to maintain the treated water at or very near the saturation point, for super-saturation results in excessive deposits, and under-saturation causes the destruction of the needed protective film.

In corrective treatment, consideration must be given to the fact that the pH value at which saturation equilibrium occurs, varies with the characteristics of the water treated.

The calcium bi-carbonate, (alkalinity) of the water and its magnesium content are the most important factors. Saturation occurs at a pH of only 7.2 with an alkalinity of 190 ppm., whereas with water containing only 15 ppm. alkalinity, the pH must be raised to 9.3.

Accordingly, in planning corrective treatment, particular attention must be given to the characteristics of the water. The fact that a pH of 8.0 for example, is successful in controlling corrosion in one system, is no criterion as to the pH that must be maintained with another supply.

Restoration of Capacity of Unlined Cast Iron Mains by Cleaning

Cleaning of cast iron mains to restore capacity is an important consideration in the problem of capacity loss.

Two important phases of this question are discussed in the report: First, the immediate increase in coefficient values and consequent increase in capacity obtainable by cleaning. Second, the rate of capacity loss subsequent to cleaning, or otherwise expressed, the maintenance of capacity after cleaning.

Data available to the Committee indicate that cleaning will ordinarily restore mains to approximately 85 per cent of their original capacity. The average value of C in 24 tests was 39 before cleaning, and 104 after cleaning. If it is assumed that the value of C for new pipe was 125, the percentage of original capacity was accordingly 31 per cent before, and 83 per cent after cleaning.

The period through which the relatively high capacity obtained immediately after cleaning is sustained, is subject to wide variations in individual cases. Some instances, particularly with small mains, are recorded, wherein the results of cleaning do not last more than four or five months. In other instances the capacity is maintained at reasonably high values for substantial periods of time.

Summary of Appendices

All of the foregoing subjects deal directly with coefficents with tar-coated cast iron pipe, with the effect of age on coefficient values, or with alternate methods of retarding or preventing capacity loss.

Certain other subjects, while not directly concerned with these questions are, nevertheless, involved in the general questions of pipe-line friction coefficients. Among these related subjects are coefficient values of steel and of concrete pipe.

Coefficient Values of Steel Pipe

A discussion of coefficent values for steel pipe, due to the wide difference in interior surface with various methods of pipe construction, necessitates a definition of the several classes of steel pipe.

The classification of alternate types by Scobey in Bulletin 150 of the U. S. Dept. of Agriculture, provides a convenient standard for summarizing the values of C for various types of steel pipe when new.

The ordinary average values of Williams-Hazen C for various classes of new steel pipe may be summarized as follows:

Corrugated pipe	60
Spiral riveted flow against laps	100
Spiral riveted flow with laps	110
Full riveted	115
Girth riveted	130
Continuous interior pipe	139

Coefficient Values of Concrete Pipe

Available data on concrete pipe indicate an extremely wide range in values of C, with instances of values as low as $C = 85$ and as high as $C = 152$. This wide range may be attributed not only to variation in surface texture or roughness of the pipe, but also to the relative uniformity of the pipe bore or, in other words, the presence or absence of undulations on the interior surface.

With these wide variations, particular care must be exercised in selecting values of C for concrete pipe.

Data available to the Committee indicate that the average value of C for the best grade, new, and large diameter precast reinforced concrete pipe, carefully manufactured, may be assumed to approximate $C = 150$. On the other hand unless rigid metal forms, rich mix of concrete, careful curing and best workmanship throughout are employed, considerably lower values must be anticipated.

Values of C for concrete pipe of different classes and different methods of manufacture are presented in the report, these values being taken largely from a comprehensive paper by Fred C. Scobey, on this subject.

Tests on concrete pipe after substantial periods of service indicate that under normal conditions the initial capacity is relatively permanent.

Summary

The vast financial loss resulting from rapid capacity reduction of pipe systems indicated by the data upon which the report is based, is a matter of major importance to the water works industry. It is believed of sufficient moment to warrant the determination, in each system, of the rate and cause of loss; as a basis for the adoption of the best preventive measures whether they are provision of permanent linings or corrective treatment of the supply.

Upon the basis of the average data on tar-coated cast iron pipe, it is found that in 19 cities the average value of C after 30 years' service was 64, as compared with a value of 88 predicted in the Williams-Hazen tables. Otherwise expressed the value of C dropped to 88 after only 11 years of service instead of after a predicted period of 30 years.

Furthermore, these average figures involve relatively large mains (20.5 inches average diameter). In 8 out of 10 systems the value of C for distribution mains after 30 years' service was less than 50—involving a consequent loss of capacity of from 61.6 to 84 per cent, as compared with a predicted loss of 37.5 per cent.

The trend curves presented in the report, illustrate a wide range of loss of capacity in various systems, and the very considerable magnitude to which such loss develops within a comparatively short period in relation to the structural life of the pipe. It is hoped that these curves will serve to interest members of this and other associations in conducting and recording tests, in order that more selective numerical data may be ultimately made available to the profession.

Elson T. Killam, Chairman; Frank A. Barbour, W. W. Brush, Laurence C. Hough, Charles W. Sherman.

EXPERIENCES IN WATER MAIN CLEANING

By CHARLES STREITHOF

Genl. Supt., Dept. of Water Works, Evansville, Ind.

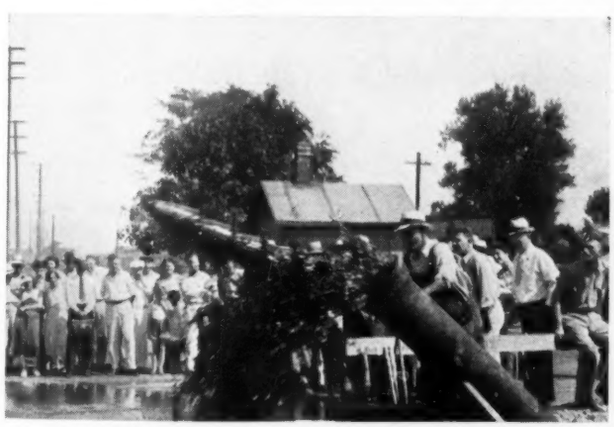
Before the Indiana Section of the American Water Works Association, I had the pleasure of presenting a paper entitled, "Inserting Gate Valves Under Pressure." (See WATER WORKS AND SEWERAGE—June, 1934.)

After the valve inserting job was completed, having seen the condition of our important mains, I felt justified in asking for an appropriation, to start cleaning some of the mains. I was able to convince our Board of Water Works Trustees of the necessity for, and the importance of, this work. It was decided to at least clean some of the larger and older mains; and, a contract was made with the National Water Main Cleaning Company of New York City, to do the cleaning.

The cleaning was started on six thousand (6,000) feet of 16-inch pipe and was continued until the contract was completed. Under the contract a total of 37,956 feet of 12, 16 and 20-inch mains were cleaned, and practically restored to their original carrying capacities. The results obtained were so gratifying and satisfactory that the Water Works Trustees were thoroughly convinced of the advisability of continuing this excellent work. A second contract was made with the same company to clean all mains of 10 to 30-inch diameters which had been laid prior to filtration. The total length of mains cleaned under the second contract was approximately 87,500 feet, and the results obtained were as good as, if not better than, those of the first contract. The Board of Trustees then decided that it would be wise to clean all pipes laid prior to filtration, and a third contract was made with the same company, to cover approximately 450,000 ft., which included principally 6 and 8-inch pipe.

Cleaning Procedure

The preparations and cleaning operations are simple, yet most effective. The section of line to be cleaned is "killed" by closing two valves, one nearest the inlet, for the entrance of the cleaning apparatus, and the other nearest the outlet. At the inlet end, the pipe is exposed and a piece of the main, about 6 ft. long, is removed and cleaned by hand. The cleaning device (sometimes called the "rabbit") is placed in it, and the section is then returned permanently to the line by employing a sleeve or coupling and using the bell end of the existing pipe. At the outlet the line is also exposed, where a smaller piece is removed, depending on the diameter, so as to permit a 45-degree bend of the same size to be attached to the end of the line to be cleaned. This joint is made with yarn only. And to the 45-degree bend is added a short piece of pipe, jointed with yarn also, to bring the line up to, and a little above, the level of the street. Then the valves controlling the lines leading off from the one to be cleaned are closed. Likewise all curbcocks are closed. It is now time to start the cleaning apparatus on its journey. The valve nearest the inlet is opened. The water entering the dead line hits the cleaning machine and as the pressure and volume increase, the machine starts to move, and if there is no obstruction in the line, such as a partly closed valve or large pieces of lead from a poorly poured joint, the machine will travel the entire length of the line to be cleaned and come out on to the pavement at the 45-degree outlet. The rate of travel is never alike in any two pipe lines of the same size and length. In cleaning 8,257 ft. of 30 in. pipe the cleaning machine traveled at a speed of 60 ft. per minute and discharged 47 truck loads of mud, not counting that which went into the sewers.



An Increasing Interest Is Shown in Cleaning Water Mains. This Job Was at Evansville, Ind.

Ample Evidence That Evansville's Mains Needed Cleaning

While the machine is moving, enough water passes it to serve as wash water, which helps to reduce the pressure of the material ahead of the machine, and long before the appearance of the machine, some of the obstructing material will be seen on the pavement. Almost from the moment that machine starts to move from the inlet end, until it is out of the main, the wash water which precedes it is very dirty. Immediately following the appearance of the machine at the outlet the water practically clears up, but it is advisable to permit the water to run a short time to thoroughly flush the line. When the machine has done its job, and the line has been flushed, it is a simple task to remove the makeup at the outlet, replace the piece of pipe there, open the valves which had "killed" the line and then those controlling the side lines, and finally the curbcocks.

Result of Cleaning

The results from main cleaning at Evansville were most gratifying. Velocity tests were run on various lines before cleaning, and the drop in pressure noted, as well as the discharge at the hydrants. The same hydrants were used after the mains were cleaned, and when the readings were taken, the difference showed an increase of 15 to 35 per cent in the water discharged. With two hydrants discharging 1,000 gallons per minute each, a drop of but two to four pounds was noted, whereas before cleaning a drop of six to fifteen pounds was common.*

In addition, practically all the valves in the pipe lines were operated and tested, and those found defective were repaired or replaced. The customary annual inspection of valves is not necessary on the lines which have been cleaned, because of the very thorough job done in conjunction with the cleaning program.

Under the three contracts 506,129 ft. of pipe were cleaned as follows:

Diam.	Feet	Diam.	Feet	Diam.	Feet
30-in.	10,725	24-in.	2,196	20-in.	13,563
16-in.	30,238	12-in.	43,007	10-in.	4,609
8-in.	65,206	6-in.	324,350	4-in.	12,236

The cost was:

Contract cost	$55,700.52
Labor furnished by water department	27,881.22
Material furnished by water department	10,329.30
Repairing paved streets	5,330.41
Total cost	$99,241.45

[*Recently a 48-inch intake main 2000 ft. long under 30 ft. of water was successfully cleaned of 8 tons of tuberculated material at Erie, Pa., to raise the coefficient from C = 57 to C = 87 and yield of 23 m.g.d. raised to 35 m.g.d. It represented a new experience in main cleaning.—Ed.]

The average cost was 19.6 cents per foot of pipe (all sizes) cleaned.

Average material cost was 3 cents per 100 ft., which included paving, pipe, lead and yarn, repairing old valves and new valves where necessary.

During the pipe cleaning, the question was often asked: "How did all the mud get in the pipes?" The answer is this: The first water works was built in 1873 and took the supply direct from the Ohio River and pumped it into the pipe system without any settling or filtering.

In 1912 when the present filter plant was placed in operation, every effort was made to flush the mud out of the pipe lines but without success. On account of lack of funds the pipe cleaning job was delayed.

The question has been asked: "How did you pay for the pipe cleaning job?" The answer is this: The Water Department has always made a nice profit but in order that our books will show no loss when making such a large expenditure at one time, a "Deferred Charge" scheme has been instituted in order to spread the costs over a period of 10 years. However, understand, the Water Department payed all of the bill in cash—the "Deferred Charge" being only a matter of bookkeeping to spread the cost out.

USE OF INHIBITORS IN CLEANING METALLIC PIPE

By ALLEN ABRAMS* and C. L. WAGNER*

Rothschild, Wis.

Water pipes in certain sections of the country are likely to become clogged by corrosion or deposits from the water. In many cases this has required replacement of the pipes, a procedure which is often costly due to the necessity of tearing out walls and floors. As a result there have been attempts to clean pipes by the use of muriatic or other acids with the intent to leave the acid in just long enough to remove the scale and yet not long enough to attack the pipe itself. This, however, is a questionable expedient and may be more expensive than the replacement of the pipes.

During the last decade considerable interest has been shown in the use of inhibitors in pipe cleaning operations involving acid treatment. These are usually nitrogenous materials such as aniline or pyridine; and, even glue and flour have been used. When small quantities of such substances are added to an acid solution the resultant mixture will attack rust or scale but will have practically no effect on the pure metal itself. Wide use has therefore been made of this principle in the acid process of "pickling" metals to effectively remove scale while rendering the loss of metal underneath almost negligible.

An example is also given of the use of this principle in cleaning the pipes of a thirty-five story office building located in downtown New York.[1]

Many of the pipes were concealed behind expensive marble walls and it was estimated that it would cost between $100,000 and $300,000 to replace this piping, not to mention the serious inconvenience to tenants. By the use of an acid-inhibitor combination the whole cleaning operation was carried out on Saturday afternoon without inconvenience to the tenants. The pipes were returned to practically their normal condition of carrying capacities and the cost of the operation was but nominal.

This method attracted our attention in 1927 and we made initial tests to determine how effectively inhibitors would reduce the action of acid on the metal. In parallel tests on galvanized iron pipes 16 per cent muriatic acid was used alone, to compare with the same acid containing 3 per cent of an inhibitor. Equal lengths of pipe were allowed to stand in each solution for six hours. At the end of that time the pipe in muriatic acid had lost 50 per cent of its weight while that in the inhibited acid had lost but 0.2 per cent of its weight. We were then satisfied that the inhibitors would effectively prevent destruction of the pipes by such acid when submerged for a relatively short period.

Working Demons Fractious

Not long afterwards two lengths of pipe, leading from the basement of our main office to the second floor became filled with rust and other deposit, completely stopping the passage of steam. It would have been relatively expensive to replace this piping and we therefore opened the two lengths at the top and cleaned them by pouring in inhibited acid, allowing it to work its way through. One overnight treatment, followed by a thorough flushing was sufficient to clean these pipes and no further trouble was encountered.

Early this year the Marathon County Board decided that it would be necessary to tear out and replace all the water piping in the Mount View Sanatorium due to the fact that it was so stopped up that it was impossible to get an adequate water supply through the system. When the matter was brought to our attention we suggested that an attempt be made to clean several lengths of this pipe and a decision could then be made as to the further course to be pursued.

Twenty-five gallons of 14 per cent muriatic acid were treated with 3 per cent, by volume, of the inhibitor.†† The treated acid was placed in a barrel to which was connected the suction of a small rotary pump. The acid was then forced upward from the basement to the second floor through a length of one-inch pipe, thence through a cross-over and down through another length of pipe to the basement. The returning acid passed through a fine screen to remove any dislodged particles and thence to the solution barrel.

At the beginning of the test a considerable amount of solid material was dislodged from the pipes and it was almost impossible to force the acid through. The pipes were then opened on the second floor, the acid mixture was poured in and allowed to flow by gravity until the pipes were filled. The bottom openings were plugged, the acid allowed to stand for eight hours and the acid withdrawn and the pipes thoroughly flushed. Examination indicated that the scale had been practically completely removed.

Control Procedure

In order to determine how effectively the cleaning was being done, three 6-inch lengths were cut from a 1-inch pipe, which was so clogged with rust and dirt that it was barely possible to get a pencil into the opening. One of these pipes was retained without treatment and the other two were connected in the circuit through which the acid was being pumped. At the end of about two hours one length of pipe was removed and found to be almost completely clean except for small patches of rust on the walls. After ten hours the other length of pipe removed for examination proved to be entirely free of rust and scale and there was no apparent action on the metal itself.

In the cleaning operation approximately 2,800 feet of pipe were treated, ranging from ½ inch to 4 inches in diameter. Estimates by George Baumgardt, who was in charge of the plumbing work, showed that the total labor costs were $870, while the cost of acid and inhibitor was approximately $20—a total of $890. Mr. Baumgardt estimated that the cost of replacing the piping would have been:

Galvanized pipe fittings and valves	$1,000
Labor for installation	5,000
Plaster, concrete floor and repainting	2,500
Total	$8,500

*Department of Research and Development, Marathon Paper Mills Co., for which the senior author is Technical Director. Mr. Wagner is chemist.

[1]"Removing Rust from a System with Piping Acid," F. N. Speller, E. L. Chappell and R. P. Russell—Chem. and Met. Engineering, July, 1927.

††Inhibitors are available, from several of the larger chemical companies—Barrett & Co., Monsanto Chemical Co., General Chemical Co., et al.

COMPRESSED AIR FLUSHING OF SMALL MAINS*

By R. F. BROWN

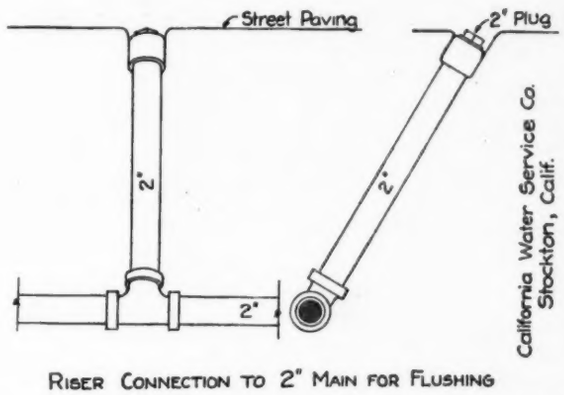
Plant Manager, California Water Service Co., Stockton, California

R. F. Brown

Many water systems in the older California towns, like Topsy, just grew without any suggestion of planning for the future. Stockton was no exception. As a consequence we found ourselves with a great many 2-inch lines in the thinly populated areas.

We have for many years followed the practice of flushing small mains and all dead ends regularly by opening fire hydrants and flusher valves and simply allowing the water to flow from the main under normal pressure of 45 pounds until the main is apparently clear. Under this program all dead ends and all small mains are given ordinary flushing, approximately at intervals of every two months.

This method, however, does nothing but freshen the water in the dead ends and small mains. In order to effect a more lasting cure for taste and odor complaints, we decided to try boosting the pressure in the main with air to attempt to break loose more of the troublesome algae and other deposited material that attaches to the pipe wall. All of our dead ends, regardless of size, and at least every other block of our 2-inch lines have what we call flusher-risers installed for the convenience of our periodical flushing program—see sketch.



RISER CONNECTION TO 2" MAIN FOR FLUSHING

Air Flushing Operations

Compressed air is put into the line through a service connection midway between two flusher-risers after we have first closed the shut-off valves on the intervening services. The valve on the flusher-riser is then opened. All water in the line is forced out through the riser, by air under 90 pounds pressure. As soon as the air has expelled all the water from the line it is shut off and water under our ordinary pressure is run through the line to sweep out, through the flusher-riser, all particles of scale, sand or foreign matter that have been loosened by the air "shooting." We proceed in this manner alternately turning into the line air under 90 pounds pressure and water at 45 pounds until the flushing water leaving the risers no longer carries with it any scale or other foreign matter.

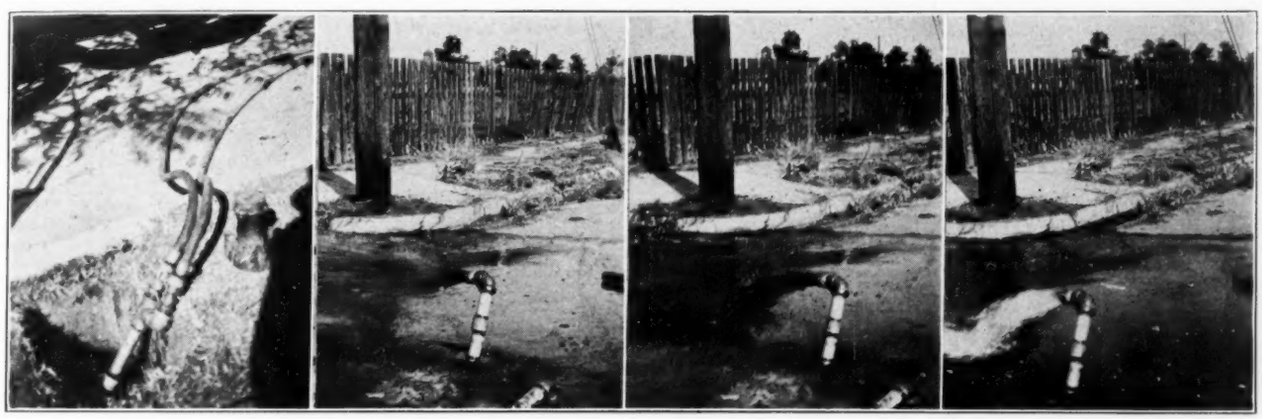
This system is apparently successful in accomplishing our purpose and it is economical, because the equipment required is only a portable air compressor and an air storage tank to provide a volume of air under pressure. No expensive cutting of mains or pavement is required and most jobs can be handled with a three-man crew.

When we first started this system we cleaned 40,000 feet of line, mostly 2-inch, over a period of two months. The cost was from 60 to 90 cts. per hundred feet, depending upon the number of services which had to be shut off and turned on again.

The success of this method of flushing is measured by the almost complete absence of the usual recurring taste and odor complaints from consumers served by mains thus treated. It is problematical how soon we will have to repeat this treatment, because from no consumer on the first line so treated has there yet developed a recurrence of complaints.

A secondary result, not anticipated, is the increase in carrying capacity of the 2-inch lines brought about by the loosening and blowing out of a great deal of scale. Thus has resulted a reduction in complaints of poor pressure as well as the taste and odor complaints.

A Self-Told Story



Air Lines Connected (This Time Through House Service at Curb Line)

First 90 Lb. Air Shot. (Note Extension Attached to Flushing-Riser)

First 45 Lb. Water Flush. (No Argument About Need to Eye or Nose)

Clear Water (Shooting and Flush Repeated As Indicated)

*From WATER WORKS AND SEWERAGE, April, 1937.

BLOWING OUT SERVICE LINES*

By S. H. DAVIS

Superintendent, Benwood & McMechen Water Co.
Benwood, W. Va.

Most every water works operator will agree that a low pressure complaint can cause a water company to have poor, or at least "razor-edged," public relations between the affected customer and the company.

However, unless the condition is caused by insufficient main line capacity, the consumer's line, as well as the company's service line, is usually the cause of the low pressure complaint. Attempts to convince the affected customer that he should renew his lines usually brings the following question or statement: "Suppose I do renew my lines, maybe your line is stopped up between the main line and my property. How about you people doing a little digging first?" To answer that question to his satisfaction, usually means to remove meter, if located at property line or curb plot, or cut service line at curb-stop, and let him see for himself. If the pressure is poor and he sees it, he becomes very positive that he won't spend a dime until given better water pressure. He thinks it is high time that the water company correct that condition and he wants it done *"right now."*

Naturally, anyone responsible for the operation of a water company wants the customers satisfied, but on the other hand, he hates to dig into a paved street to disconnect a service from the corporation, or to renew the service line to satisfy the customer.

Method of Cleaning

We have had the usual number of low pressure complaints with all the grief that goes with them. We have tried various methods of cleaning out service lines and the method we now use is the compressed air and rock salt method.

The equipment consists of the following parts:

(1) Cylinder of compressed air—*don't use oxygen.*
(2) 15 ft. (2,000-lb.) wire braided hose with suitable connections to connect to service line.
(3) 1 (2,000-lb working pressure) check valve.
(4) 1 (2,000-lb.) working pressure) forged cross tee.
(5) 1 (2,000-lb. working pressure) angle valve—wheel type.
(6) 1 (1,000-lb.) relief valve—set at 600 to 800 lbs.
(7) 1 (1,800-lb.) pressure gauge.
(8) Necessary nipples to connect fittings and for connections on air cylinder (use extra heavy nipples).

The method of blowing out service lines is as follows:

(1) Make necessary test for low pressure.
(2) Fill wire braided hose with about 2 ft. of coarse rock salt (ice cream salt) and connect to service line with curb or meter stop in the off position.
(3) Close angle valve on tank connection—hose.
(4) Open curb or meter stop.
(5) Just crack needle valve on compressed air tank and then close *quickly* with one hand.
(6) Open angle valve *immediately* with other hand—the "shot" is fired.
(7) Allow muddy water from service to blow through angle valve until water is clear.
(8) Connect up line.

It is advisable to "crack" a nearby fire plug so that the excess air will go out through plug.

The action of the compressed air is very quick and a surging will be noticed in the armored wire hose, but after a few seconds the surging will stop and the water will flow out of the angle valve with normal pressure. As the rock salt enters the service line it literally scrapes the incrustation away from the line and the rock salt dissolves in the main line. No complaint of salty taste in the water has resulted, however.

This system is only recommended where lead or copper service lines have been installed. There is too much danger of rupturing a weakened steel line which is badly corroded.

The photographs show the results of this method. The height of water above ½-inch riser pipe (30 in. above curb stop) was 3 in. only. But, after blowing out service line the height of water was 36 in., indicating increased pressure and volume obtained.

We have found that after we do our part, should the pressure continue low, consumers become convinced that their piping is either corroded or too small. In most cases they will remedy their condition. We do not blow service lines from cellar to property line, because we feel that is the plumber's job.

The average time required to attach the equipment and blow out a service line is only 15 minutes. Our cost for a cylinder of air is approximately $2.50.

*An article published in WATER WORKS AND SEWERAGE, October, 1935.

Dribble *Load* *Shoot* *Gush*

One That Needs Blowing; Loading Armored Hose with 2 ft. of Rock Salt; the Quick Shot of Compressed Air (Note Man with One Hand on Cylinder Valve, the Other on Release Angle Valve). Results—Plenty of Water and a Satisfied Customer.

TREATING WATER TO PREVENT CORROSION*

By JOHN R. BAYLIS†

Associate Editor, Waterworks & Sewerage

The writer, in 1930, presented some of the factors involved in preventing corrosion of water pipes.[1] Curves were given to show the solubility equilibrium of iron and zinc compounds in the presence of their respective metals. These curves (Fig. 1) show that practically no iron or zinc will exist in solution when the pH is above 8.0. At a pH of 7.0 several parts per million of either metal may exist in solution in some form in the absence of oxygen, and at a pH of 6.5 quite a large amount of iron or zinc may be found in solution in the absence of oxygen. The article explained how corroding iron took all the free CO_2 and much of the half-bound CO_2 from the water, leaving the water distinctly alkaline where there was no dissolved oxygen present. If the water contained dissolved oxygen the iron was precipitated as a hydrous oxide. Section of a 1-in. cement lined pipe, which had been in service for 50 years at Danvers, Mass., also was shown. The interior of the pipe was in fairly good condition, indicating that the lining was still giving very good protection.

Carrying Capacity of Pipes Greatly Reduced by Incrustation Resulting from Corrosion.—That the carrying capacity of iron pipes may be greatly reduced by tuberculation and incrustation as a result of corrosion is well known to most every one.

Haydock[2] describes how cleaning the tubercles or incrustation from several pipe lines increased the flow. One line carried only about one-half its theoretical capacity, and another about two-thirds. Cleaning a pipe line 3 miles long increased the capacity to the extent that a pumping station could be abandoned, and cleaning another line 5 miles long also enabled the abandonment of a pumping station. The friction loss through a 12-in. line 4 miles long 20 years old was nearly three times that of a new line. The capacity was increased by approximately 35 per cent and the delivered pressure by 20 lb. The gravity delivery of a 16-in. pipe 10.5 miles long was increased 60 per cent by cleaning. Cleaning a 13 mile section of a 12-in. pipe

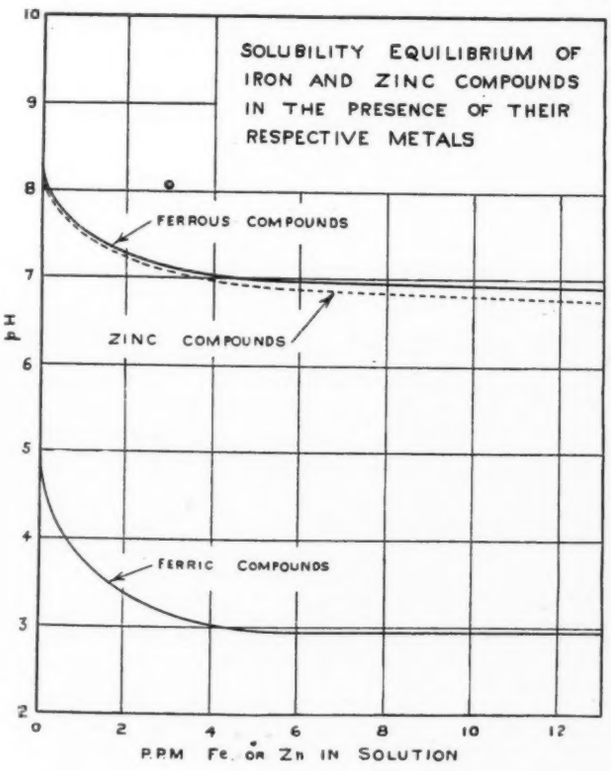

SOLUBILITY EQUILIBRIUM OF IRON AND ZINC COMPOUNDS IN THE PRESENCE OF THEIR RESPECTIVE METALS
FERROUS COMPOUNDS
ZINC COMPOUNDS
FERRIC COMPOUNDS
pH
P.P.M Fe. or Zn IN SOLUTION

Fig. 1

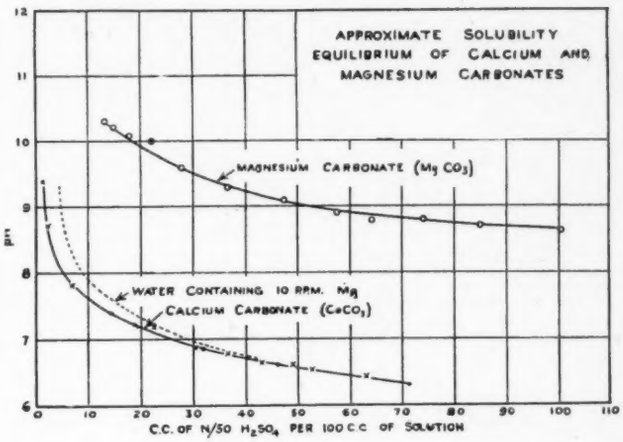

APPROXIMATE SOLUBILITY EQUILIBRIUM OF CALCIUM AND MAGNESIUM CARBONATES
MAGNESIUM CARBONATE ($MgCO_3$)
WATER CONTAINING 10 P.P.M. Mg
CALCIUM CARBONATE ($CaCO_3$)
pH
C.C. OF N/50 H_2SO_4 PER 100 C.C. OF SOLUTION

Fig. 2

line 22 miles long, which had been in service about 16 years, increased the capacity approximately 35 per cent, and cleaning another section of the line 6 miles in length increased the carrying capacity to 46 per cent.

Increased Pumping Pressure or Larger Mains Very Expensive.—In some instances it is possible to deliver the desired amount of water through distribution systems that have become partially clogged by increasing the pumping pressure as the friction losses increase, or to install booster pumping stations on the distribution system in certain sections where the pressure is low. Haydock refers to the delivered pressure being increased 20 lb. by cleaning the pipes in one instance. Assume that it was desired to maintain this 20 lb. increased pressure, evidently it was quite expensive to do it at the pumping station. A fair average of the cost of lifting one million gallons of water 1 ft. in height is probably 5 ct. Twenty pounds is equivalent to about 46 ft. in head. In this case it would cost about $2.30 per million gallons to maintain the increased pressure.

If corrosion is going to reduce the carrying capacity of the water mains in a certain city 50 per cent within 20 years, what is the best way of handling such a situation? Should mains be installed large enough to give the desired capacity with a 50 per cent reduction in carrying capacity? The cost of such an investment over what would be necessary if there was no corrosion very likely would be much more than the cost of making the water reasonably non-corrosive.

With the exception of feeder mains, engineers usually design the water distribution system for fire protection. How many engineers allow for a 50 per cent reduction in the carrying capacity of the pipes within 20 years where the water is corrosive? How many make any distinction whatever in the design where the water is corrosive and where it is not corrosive? The writer is of the opinion that corrosion has not been given its proper consideration in the design of water systems. This is largely due to the lack of specific information in the past as to how much the carrying capacity will be reduced within a certain time.

Treatment with an Alkali for Partial Protection.—The literature on the treatment of water to prevent corrosion indicates quite conclusively that the corrosiveness of water may be greatly reduced by proper treatment. It seems that some of the authors of articles on corrosion prevention do not fully realize the importance of a film for protection. So long as iron stains are prevented, some think that this is all the treatment that is necessary. As a matter of fact the carrying capacity of the pipes may be reduced just as rapidly as before, because most of the corroding iron is deposited near where the corrosion is taking place and forms large tubercles that are more effective in reducing the carrying capacity of the pipes than if the rust was

*Excerpts from an article which appeared in WATERWORKS AND SEWERAGE.

†Physical Chemist, Bureau of Engineering, Chicago, Ill.

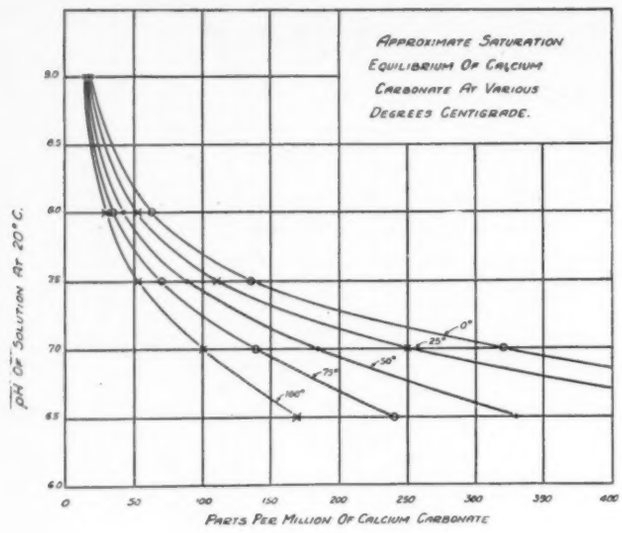


Fig. 3

deposited fairly uniform over the surface of the pipe. Treatment just to the point where red water complaints cease may not materially reduce the cost to the water department for cleaning pipes, constructing new mains, and increasing the pumping pressure.

Water Just Saturated with Calcium Carbonate s the Most Desirable Equilibrium.—As a general rule, it might be said that water saturated with calcium carbonate is the most desirable equilibrium when everything is taken into consideration. This is not strictly true for very soft waters, for it is desirable to have the water slightly supersaturated part of the time so as to form a thin protective film. Where the calcium carbonate alkalinity of the water is below 30 parts per million the application of lime to produce a slight supersaturation of calcium carbonate should be done with considerable care, otherwise caustic water might be produced. After a thin coating has been formed on the pipes the water should be kept saturated with calcium carbonate practically all the time to keep the coating from being dissolved. It is admitted that the very soft waters are the most difficult to protect, for we are working with equilibriums difficult to maintain exactly on the saturation point. It may be almost impossible to do this with the force available in small plants and it may be necessary to sacrifice some protection to avoid occasional caustic taste in the water. There is no reason why large plants with skilled supervision should not be able to maintain a fairly constant equilibrium.

Table I—Rapid Increase in pH Caused by Corroding Iron

Alkalinity	Time in Contact with the Iron Minutes	pH	Fe in Solution
39	0	7.2	
	1	7.3	
	2	7.4	
	3	7.7	
	5	8.2	
	10	9.2	
	15	9.4	
35	20	9.6	0.0tr

Where water has a calcium carbonate alkalinity in excess of about 30 it is easier to protect the pipes. If this water is placed in contact with an iron surface the iron going into solution will take up all the free Co_2 that is in the water and part of the half-bound CO_2. Table I shows how quickly the pH changes in water exposed to iron lathe turnings. After the pH reaches 8.1 no free CO_2 is present. This was due to the CO_2 combining with the corroding iron.

At any point on the surface of an iron pipe where corrosion starts to take place due to the surface becoming exposed in some manner, there is a tendency for the iron going into solution to take up the free and part of the half-bound CO_2, producing a supersaturation of calcium carbonate in the immediate point where corrosion is taking place. This supersaturation helps to quickly form a coating over the exposed surface both by precipitating the iron compounds and also some calcium carbonate, especially when the water has a fairly high alkalinity. If the water in the mains is saturated with calcium carbonate, then the precipitated calcium carbonate will not be dissolved out of the percipitate. It will remain where it is precipitated to offer protection against further corrosion.

Most natural waters contain magnesium carbonate as well as calcium, and the presence of a considerable amount of magnesium may materially alter the equilibrium curve. This is shown by the curves in Fig. 2. The presence of sodium carbonate also alters the curve. When sodium carbonate is present the only way the saturation equilibrium of the water in regards to calcium carbonate can be determined is by actual trial.

Temperature also has an effect upon the saturation equilibrium of calcium carbonate. The curves shown in Fig. 2 were determined at room temperature, that is, about 20 to 22° C. The other curves are based on actual tests, but not enough were run to state that the curves are absolutely correct. They should be regarded as somewhere near the true lines.

Corrosion prevention by treatment of the water has been demonstrated to be practical and economical. This being true, then it seems that all corrosive waters should be treated.

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[1]Baylis, J. R. How to Avoid Loss by Pipe Corrosion. WATER WORKS ENGINEERING, 83:13-14, 31-32, 35-36, Jan. 1, 1930.

[2]Haydock, C. The Cleaning of Cast Iron Water Pipe Lines. Jour. Am. Water Works Assoc., 11:533-4, May, 1924.

The Influence of Dissolved Oxygen on Corrosion Losses

Engineers and chemists are constantly studying the theories and mechanics of corrosion because it is only through better understanding of fundamentals that they will be able to diminish losses due to corrosion.

Thirty years ago, R. W. Whitney, now vice-president of the general Electric Company, announced that the corrosion of metals was an electrochemical process and this view is now generally accepted. When a metal is in contact with even slightly acidic solutions, corrosion takes place by the chemical process of the metal replacing the hydrogen in the acid. The acid dissolves the metal and thereby hydrogen is released. The same holds for corrosive waters.

Released hydrogen coats the metal surface with an electrically charged layer that prevents the chemical reaction from continuing at the initial rate. If the hydrogen layer is built up to a sufficient thickness the reaction is practically stopped. However, under natural conditions, the hydrogen combines with the oxygen of the air or that dissolved in the water to form water and solution of the metal goes on. The *amount of oxygen* available to remove the protective hydrogen blanket determines the extent of corrosion.

Impure metals are corroded more quickly as a rule than pure metals. Electrochemists believe that this is due to the impurities taking up the oxygen. Contrary to the popular belief, however, pure metals are subject to corrosion under the action of certain acid solutions. Prof. O. P. Watts of the University of Wisconsin has recently shown that if oxygen is absolutely excluded copper will not corrode in a solution of sulfuric acid, a reaction that is very rapid in the open.

The importance of the dissolved oxygen content of corrosive water is thereby once more emphasized. When this element is present in high concentration a higher pH value must be maintained to prevent corrosion of mains than otherwise; and, particularly of household services or piping subjected to increased temperatures which create accelerated attack.

This suggests that there is some question as to the merits of aeration of waters which are normally aggressive, unless the pH value is raised sufficiently by alkali addition to reduce the hydrogen ion concentration considerably; below that which is commonly considered to represent a neutral water. It has in fact been demonstrated that ofttimes waters high in oxygen content and low in hardness must be raised to pH 9.5 in order to check even the cold water corrosion of mains. In some aerated waters a pH value of 10 to 10.5 is required, which is costly and questionable practice with public supplies.

DETERMINING THE NECESSARY TREATMENT TO PREVENT CORROSION*

By P. L. McLAUGHLIN

Sanitary Engineer, West Virginia Water Service Co., Charleston, W. Va.

Difficulties from red water and corrosion have necessitated corrective treatment at nine of the fifteen water works plants owned by the West Virginia Water Service Company in the State of West Virginia.

All nine of the supplies considered are purified in rapid sand filtration plants. Lime is applied to the filtered water in the clear water wells at seven of the plants.

Satisfactory experiences can be cited for the plants using corrective treatment. Without exception, the managers of these properties report that present conditions are far superior to those experienced prior to the use of the treatment. Practically no complaints of red-water are received by them today except occasionally from consumers residing on dead ends of the distribution systems. Furthermore, all managers report the presence of a white film, or protective coating, in the pipes of their distribution systems, although the extent to which this coating has been deposited varies with the different waters and seems to be dependent upon the size of the distribution system, the length of time the treatment has been in use and the accuracy with which it has been carried out.

The Method Adopted

The treatment consists of producing a plant effluent which is in "chemical balance"; that is, at the saturation point with respect to its power to dissolve calcium carbonate. This procedure is based on accepted principles that a water which no longer dissolves calcium carbonate should tend to form a protective coating in the mains and thus prevent corrosion. The writer uses the following procedure for rapidly determining, on a single sample of water, the correct pH to maintain through lime addition.

The procedure adopted assumes that the degree of undersaturation or the degree of supersaturation (within the limits required for performance of the test), of a water at a given alkalinity and pH is a function of the degree of increase or the degree of decrease in the total alkalinity of that water after contact with an excess of pure $CaCO_3$. Therefore, to determine the pH value at which the saturation point of an undersaturated water is attained, it is only necessary to increase the pH of a sample of that water (with lime) through a series of arbitrary pH values. Then, determine the degree of undersaturation, or supersaturation, as expressed by parts per million gain or loss in total alkalinity after treatment with $CaCO_3$, of the samples treated to produce increasing pH values. The use of a graph is then resorted to. The following example of the method as actually applied will illustrate the procedure.

*From WATER WORKS AND SEWERAGE—March, 1936.

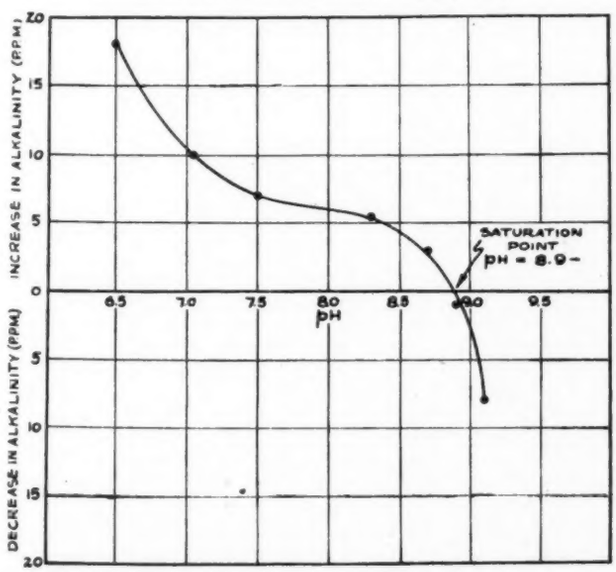


Fig. 1—Saturation Point of Charleston Filtered Water

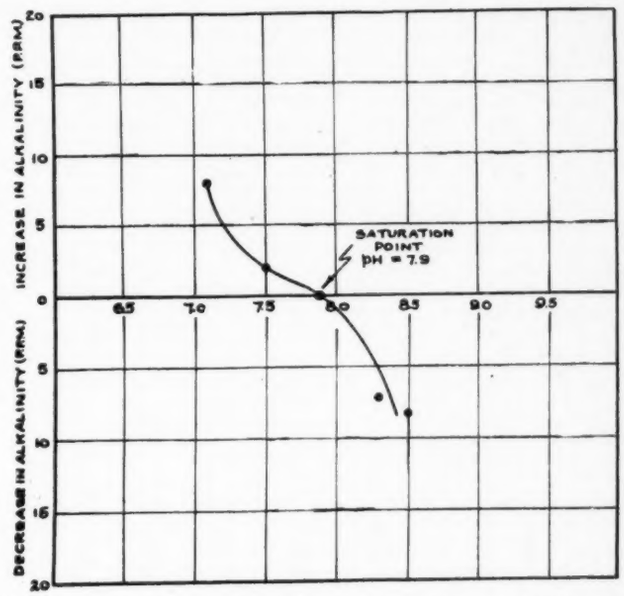


Fig. 2—Saturation Point of Nitro Filtered Water (Oct. 23, '35)

Test Procedure

A one gallon sample of filter effluent, taken ahead of plant treatment with lime, was collected in a gallon glass bottle. The pH of the sample was determined and found to be 6.5 and the total alkalinity (Methyl Orange) 18 p.p.m. About 200 c.c. of the sample was then transferred from the bottle to an Erlenmeyer flask. One teaspoon full of C.P. powdered (precipitated) $CaCO_3$ was added to the water in the flask and stirred for five minutes. The carbonate was then allowed to settle, after which the supernatant liquid was filtered through filter paper and the alkalinity determined on the filtered portion. This alkalinity was 36 p.p.m., an increase of 18 p.p.m. over that of the original sample in the gallon bottle. The increase in alkalinity was then plotted against the original pH value (6.5), thus determining the first point on the curve. (See Fig. 1.)

Hydrated lime in solution (lime-water) was then added gradually to the original sample in the gallon bottle and thoroughly mixed by stirring until the pH of the sample had increased to approximately 7.0—in this instance, 7.05. At this pH the alkalinity was determined on an unfiltered portion and found to be 24 p.p.m. A 200 c.c. portion of the sample was transferred, as before, to an Erlenmeyer flask; $CaCO_3$ was added, mixed for 5 minutes, settled, filtered and the alkalinity of the filtrate determined. It had increased to 34 p.p.m., representing a 10 p.p.m. pick-up of alkalinity from the carbonate as compared to an 18 p.p.m. pick-up in the first test on the unlimed sample. The second point on the curve was thus located, the increase in alkalinity of 10 p.p.m. being plotted against the pH of 7.05, which was that of the lime treated test sample.

More lime was then added to the water in the gallon bottle until the pH was raised to 7.5. At this pH value the alkalinity was 25 p.p.m. As before, a portion of the sample was removed and treated with $CaCO_3$, and an increase in alkalinity of 7 p.p.m. was observed. This increase was plotted against pH 7.5, forming the third point on the curve.

In a similar manner the pH of the sample in the bottle was raised with lime to pH values of 8.3, 8.7, 8.9 and 9.1 and the differences in alkalinities after treatment with $CaCO_3$ were plotted against each of these pH values.

It will be noted from the curve that at pH 8.7 the water was only slightly undersaturated, the increase in alkalinity after treatment with $CaCO_3$ being but 3 p.p.m. At a pH of 8.9, however, the alkalinity *decreased* 1 p.p.m. after treatment with $CaCO_3$, showing that at this pH the water was slightly supersaturated and some calcium alkalinity had deposited out on the suspended carbonate. Therefore, the exact point of equilibrium lay between these two pH values, or for all practical purposes at pH 8.9—see Fig. 1. The pH of the sample in the bottle was then increased to 9.1 in order to portray the trend of the curve more accurately.

Having determined the saturation point of the sample by the above procedure, its adaptation to plant control consists merely in adding enough lime to the filtered water to maintain a pH value of 8.9 or thereabouts in the plant effluent.

Inasmuch as free carbon dioxide gas (CO_2) influences the solubility of calcium carbonate in water, care should be taken in carrying out the procedure not to allow the sample to come in contact with the air any more than possible, and to avoid shaking or violent agitation of the sample. Removal of portions of water from the original sample should be made with a transfer pipette and a good grade of filter paper should be used for filtering the portions treated with $CaCO_3$. The procedure is carried out at room temperature and it is believed that a negligible error may be introduced thereby, since in the case illustrated the temperature in the Charleston laboratory was some 10 to 15 degrees higher than the temperature of the water in the clear well and in the mains.

A convenient and explanatory method of recording the data obtained in carrying out the procedure is shown below:

Filter Effluent—Charleston, October 17, 1935

pH 6.5	$CaCO_3$ added, mixed		Undersaturated
Alk. 18	settled and filtered	Alk. 36	+18
Lime added:			
pH 7.05	$CaCO_3$ added,		Undersaturated
Alk. 24	etc.	Alk. 34	+10
Lime added:			
pH 7.5	$CaCO_3$ added,		Undersaturated
Alk. 25	etc.	Alk. 32	+7
Lime added:			
pH 8.3	$CaCO_3$ added,		Undersaturated
Alk. 27	etc.	Alk. 33	+6
Lime added:			
pH 8.7	$CaCO_3$ added,		Undersaturated
Alk. 28	etc.	Alk. 31	+3
Lime added:			
pH 8.9	$CaCO_3$ added,		Supersaturated
Alk. 32	etc.	Alk. 31	—1
Lime added:			
pH 9.1	$CaCO_3$ added,		Supersaturated
Alk. 35	etc.	Alk. 27	—8

The Influence of Calcium Bicarbonate In the Water to Be Treated

It is known that when the calcium carbonate content of a water is less than 25 to 35 p.p.m., the calcium carbonate content must be built up to this amount before corrosion can be effectively prevented. The alkalinity of the water used to illustrate the procedure was but 18 p.p.m., and the water was therefore below the prescribed limits as to its calcium carbonate content. However, this deficiency was automatically taken care of in the procedure and in its adaptation to plant control methods by the use of lime which increased the calcium carbonate content to the point required for saturation. Several of the water supplies requiring corrective treatment operated by the West Virginia Water Service Co. normally, or occasionally, have calcium carbonate contents in excess of the minimum requirements. The procedure for determining the pH of the saturation point for these waters is carried out with lime in the same manner as described.

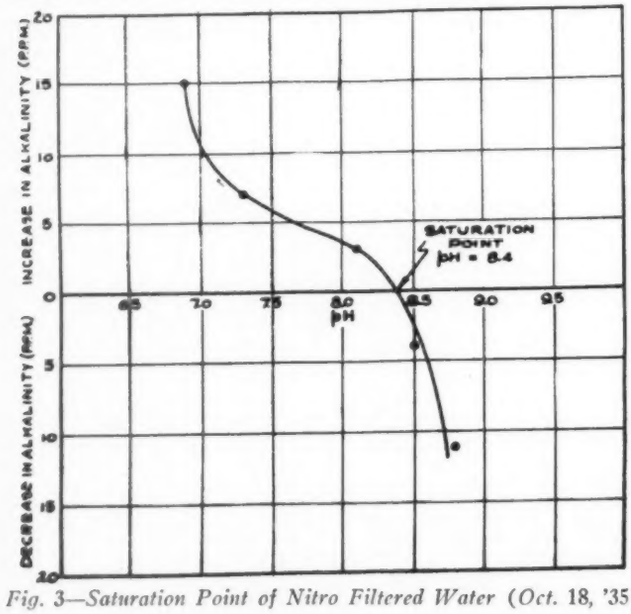


Fig. 3—Saturation Point of Nitro Filtered Water (Oct. 18, '35)

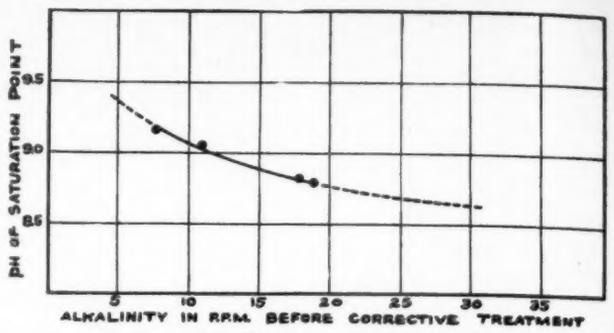


Fig. 4—pH Saturation Point vs. Total Alkalinity—Operating Curve

Figure 2 shows the curve obtained by the procedure on such a water. The sample was taken recently from the filter effluent of the Nitro plant which treats Kanawha River water and had a pH of 7.1 and an alkalinity of 47 p.p.m.

The saturation point of the same supply, determined five days previously, is shown by Fig. 3. In this case, the pH of the filter effluent before lime addition was 6.9 and the alkalinity was only 39 p.p.m.

Inasmuch as the pH of the saturation equilibrium with calcium carbonate of any water depends, among other factors, upon the concentration of dissolved alkaline compounds in that water, it has been found, as would be expected, that the pH of the saturation point varies with changes in the chemical composition of the water. As the alkalinity decreases, the pH and total alkalinity at the saturation point increases and vice versa.

Protective carbonate coatings will be quickly dissolved and removed if the water in contact with them is undersaturated. Also, such coatings will be built up too rapidly if the pH of the water is carried too high above the saturation point. Therefore, to practice effective control in the treatment for the prevention of red-water and corrosion on a supply of fluctuating chemical character it is necessary to vary the pH of the plant effluent as frequently as is required to meet changing raw water conditions.

A General Curve for Plant Control

For a given supply, saturation points (pH values) can be determined by the procedure for various alkalinity values and a saturation curve plotted from this data. Figure 4 represents such a curve under process of development for the Charleston water. With experience the number of trial tests can be reduced, and once the curve has been established for a supply, the approximate pH of the plant effluent of that supply required to bring the water to equilibrium with calcium carbonate can be selected at once by merely determining the total alkalinity of the water to be treated. Then, if desired, a single check test should confirm this value if made on the plant treated water.

When corrective treatment is first applied to a water supply it is probably best to deliver the water to the distribution system in a slightly supersaturated condition for a period of several months or until a thin protective film has been built up in the mains. The treatment should then be reduced and maintained as closely as possible at the pH of the saturation point with calcium carbonate. It will be found difficult, if not impossible, to maintain the pH at exactly the desired value under ordinary methods of plant control but the slight variations experienced should not impair the success of the treatment in so far as overall practical results are concerned.

In closing, it should be pointed out that the procedure presented in this paper is not held to be without errors but it is believed that the procedure provides a rapid and workable method, sufficiently accurate for the purposes required, whereby the pH of the saturation point of a water can be obtained from a single sample of that water, thereby eliminating cut and try methods on a plant scale. At least it has been successfully applied to the low alkalinity waters encountered in several West Virginia plants.

CHECKING TUBERCULATION BY CHLORAMINE TREATMENT*

By J. WALTER ACKERMAN

General Superintendent, Consolidated Water Co., Utica, N. Y.

The results from the ammonia-chlorine treatment in suppressing tuberculation of the 12-mile cast-iron supply main at Utica, N. Y., constitute a new chapter in corrosion control and depreciating capacity values of water mains.

When Mr. Ackerman first reported his observations informally before the American Water Works Association in 1934, he considered the findings both interesting and indicative, rather than conclusive. Amongst his audience were many skeptics. A year later sufficient supporting data had been accumulated by him to warrant a further informal report before the same association. Now, still a year later, the results are more than ever convincing. It was with this in mind that WATER WORKS AND SEWERAGE asked Mr. Ackerman to present to its reader his data-graphs and the accompanying report of the continuing effectiveness of the treatment which maintains sterile conditions throughout the 12-mile main.—Editor.

The Consolidated Water Co. of Utica, N. Y., constructed in 1906 a single 24-inch cast iron water main for transmission purposes to bring water from the West Canada Creek at Hinckley, N. Y., to Marcy Summit, a distance of 12.1 miles, for the purpose of supplying the city of Utica with water from this source in addition to that already supplied from the southern group of reservoirs. This supplied sufficient water for use in the city until 1922, when the use had increased and delivery of this line had diminished to a point where it was only delivering about 8.5 M.G.D.

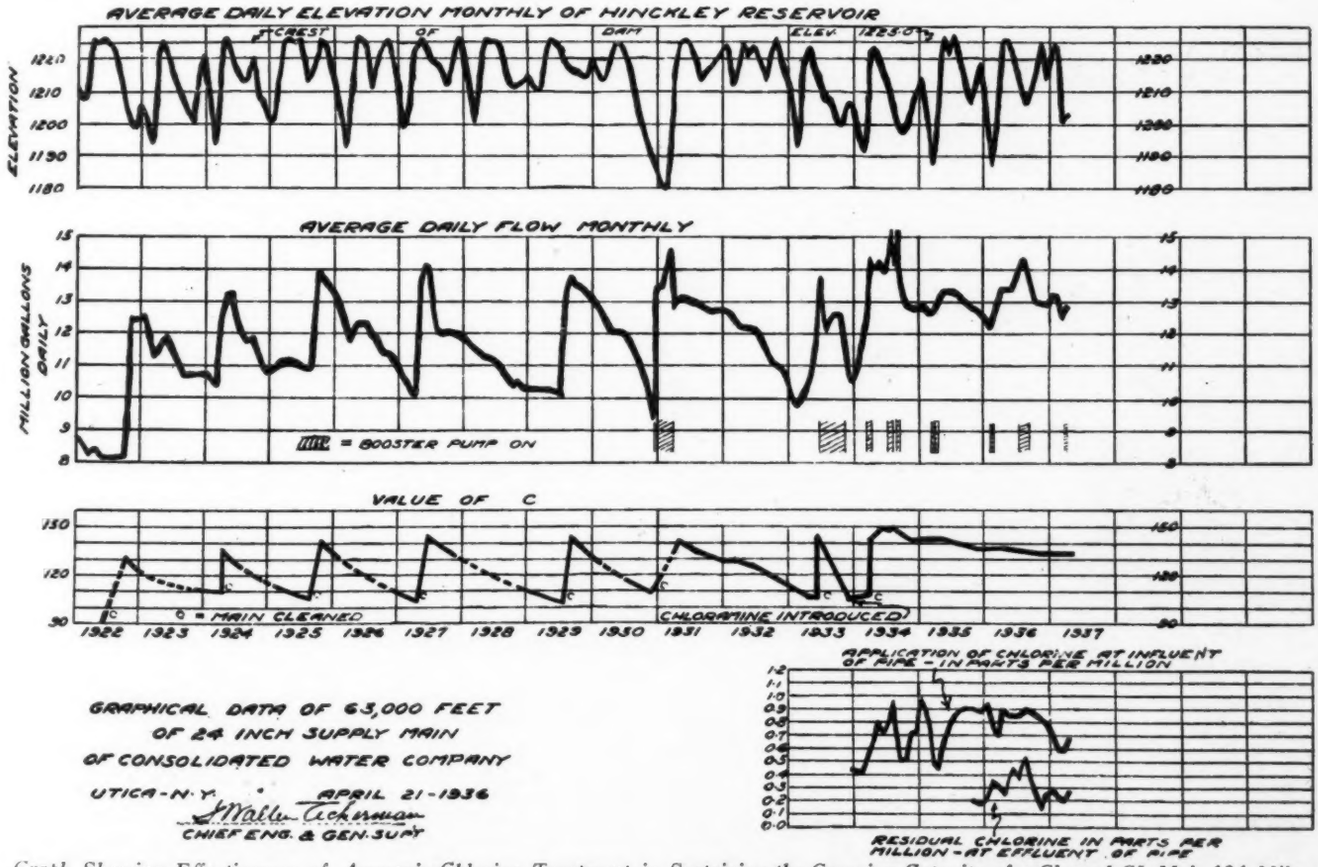
Records in the office indicate that in 1917 this line was examined by Metcalf & Eddy, Engineers, and the value of "C" in the Hazen-Williams formula was found to be 109. On July 5, 1921, "C" had dropped to 95, and in November of the same year it had dropped further to 93.5. It later became necessary to clean this line and the National Water Main Cleaning Company was engaged for this purpose and cleaned it on October 5, 1922.

Table A shows the number of times the main has been cleaned since that date and the various "C" values before and after cleaning.

TABLE A

Date Cleaned	Months Since Previous Cleaning	Reservoir Elevation	—Delivery— Before	After	——"C"—— Before	After
		1199.9	Oct. '22	Oct. '22	June '22	Oct. 8, '22
Oct. 5, 1922		1199.9	8.5	12.3	90	131
		1192.3	Mar. '24	May '22		
Apr. 1, 1924	18	1226.1	10.3	13.2	109	136
		1211.8	Aug. '25	Oct. '25		
Aug. 27, 1925	17	1220.4	10.5	13.9	106	142
		1222.7	Apr. '27	June '27		
May 4, 1927	20	1223.1	10.1	14.2	103	144
		1223.7	July '29	Sept. '29		
Aug. 6, 1929	27	1215.6	10.0	13.8	102	142
		1193.3	Nov. '30	Mar. '31	Nov. '30	Sept. '31
Jan. 3, 1931	17	1249.7	10.2	14.6	109	133
		1223.6	May '33	July '33	Apr. '33	July '33
June 16, 1933	29	1273.8	10.3	14.0	106	136
		1276.4	Apr. 2, '34	Apr. 12, '34		
Apr. 8, 1934	10	1226.1	11.9	13.7	111	144

*From WATER WORKS AND SEWERAGE, May, 1936.


AVERAGE DAILY ELEVATION MONTHLY OF HINCKLEY RESERVOIR
CREST OF DAM
ELEV. 1223.0
ELEVATION
AVERAGE DAILY FLOW MONTHLY
MILLION GALLONS DAILY
= BOOSTER PUMP ON
VALUE OF C
C = MAIN CLEANED
CHLORAMINE INTRODUCED
1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937
APPLICATION OF CHLORINE AT INFLUENT OF PIPE - IN PARTS PER MILLION
RESIDUAL CHLORINE IN PARTS PER MILLION - AT EFFLUENT OF PIPE
GRAPHICAL DATA OF 63,000 FEET
OF 24 INCH SUPPLY MAIN
OF CONSOLIDATED WATER COMPANY
UTICA-N.Y. APRIL 21-1936
J. Walter Ackerman
CHIEF ENG. & GEN. SUPT.

Graph Showing Effectiveness of Ammonia-Chlorine Treatment in Sustaining the Carrying Capacity of a Cleaned CI. Main 12.1 Miles in Length. Compare the Friction Coefficient Curve for 1930 and 1934 with That for 1934-1937

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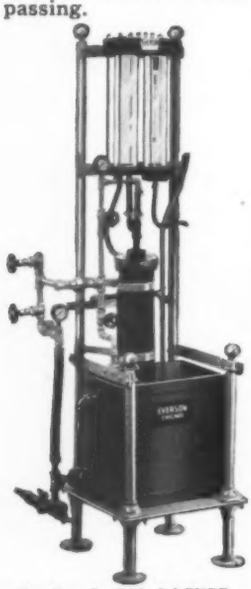

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Until December, 1933, this 24-inch line had carried nothing but untreated water, chlorination being carried out at the local distributing reservoirs. In December, 1933, chlorine-ammonia treatment of the water was started at Hinckley, and the "C" value at the time the treatment began was 105. In April, 1934, just prior to the last cleaning, a measurement of "C" showed a value of 111, an apparent improvement of about 6 p.c. in carrying capacity after the four months of treatment by chloramines, without cleaning.

The last cleaning of this line was done as noted on April 8, 1934, and the "C" value was raised from 111 to 144. No mechanical cleaning has been done since that date, but the line has been continuously treated with chloramines to the present time. On April 16, 1936, the last determination of the "C" value was 138.

The graph accompanying this article shows the variations in the level of the water in the Hinckley Reservoir, which varies the head on this pipe line and consequently varies the flow due to this change in head. It shows the monthly average flow in each month from 1922 to date, also the chlorine application and the resultant "C" value before and since the application of the ammonia-chlorine treatment. The results seemingly speak for themselves.

Method of Checking "C" Value

Just a word as to the method of checking this "C" value. Careful and rechecked determinations of reference level points at each end of the 12.1 miles of pipe have been made. Consequently, physical observations of the water level in the standpipe at one end of the line and the water level at Hinckley Dam at the other end give the actual slope. The amount of flow is determined by a venturi meter, but at no time has the value of the amount of flow been accepted except after being checked by manometer or pitot tube, and, in fact, a number of these determinations are made either by the manometer on the venturi tube or the pitot tube near this same place. Therefore there are some slight variations in the determining of the "C" value of the period from April, 1934, to the present time. While there appears to be somewhat of a downward trend, it is so small as to be almost negligible, as, of course, the different methods of computing the flow vary about 2 to 3 per cent, according to the method used for this determination, which is as close as can be expected for equipment of this nature.

The Marcy standpipe, which is at the lower end of the 12.1 miles of 24-inch pipe in question, is 2.3 miles from Marcy Reservoir, where the actual chlorine residual is taken, as the Marcy standpipe is in a more or less inaccessible location a part of the year. The residual obtained and shown on the chart is less, therefore, than the actual residual at the end of the 12.1 miles of 24-inch pipe, as the chlorine demand in the 2.3 miles to Marcy Reservoir is considerable in this uncleaned and badly tuberculated section of pipe, which we believe is gradually being cleaned by the action of the chloramines.

Addenda—1937

The above article was prepared in April, 1936. From Mr. Ackerman comes the following advice and a new graph, which carries forward the flow and friction data into 1937, although the graph carries the original date—April 21, 1936. The author explains that the data are checked by frequent readings taken from a checking manometer on the venturi tube, and the use of a Cole rod and Lanham rod. These check readings have shown a difference of but 1 to 3 points in obtaining "C" values of 134 to 142 in the Utica situation.

Mr. Ackerman states: "It will be noted that there seems to be a slight diminution of the "C" value during the past year, but hardly enough to make very much difference in our flow. As a matter of fact we are actually getting more water down now than heretofore, which, I think, is due to the fact that all of these figures constitute the result between the Hinckley Dam and our Marcy standpipe only."

"Below the Marcy standpipe to our reservoirs are two lines of pipe, one 24-inch and one a 16-inch. We know that the 16-inch is very badly tuberculated. About three years ago a test was made on it and the 'C' value was down to about 60. But, since we had at least a theoretical capacity greater than the line above, we did not clean these two lines. We do find now that the water does not stand as high in our standpipe with the same dam elevation at Hinckley as heretofore, which rather indicates that the chloramines have been gradually cleaning the 16 and 24 inch lines below the Marcy standpipe."

"These are just some added points to give you a better understanding of the problem."

LIMESTONE CONTACT BEDS FOR CORROSION CONTROL

Have Features Attractive for Small Installations

By I. M. GLACE, C.E.

Consultant and Supervising Engineer, Harrisburg, Pa.

The water served Dillsburg, Pennsylvania, is typical of that of many other similar supplies serving the considerable number of communities located in or contiguous to the Appalachian Mountains in Pennsylvania.

The following analysis of the Dillsburg water is characteristic of water of the territory—very soft and palatable, but corrosive and tuberculating:

Hardness	12 p.p.m.
Alkalinity	8 p.p.m.
Carbon dioxide	20 p.p.m.
pH	5.4

From a bacteriological standpoint the water is of high quality.

Complaints

Tuberculation of the mains had resulted in a noticeable decrease in carrying capacity and pressure losses at fire hydrants. In order to cooperate with the local fire department the water company, which is exceptionally progressive for a community of this size, retained a nationally known water main cleaning company to scrape the lines. From the standpoint of recovery in main carrying capacity this operation was a success. Naturally, the cleaning exposed some fresh metal, and complaints of "red water," laundry stains, and iron tastes were received by the company. It was then that the writer and the Wayne Laboratories, with whom he is associated, were retained to recommend relief measures.

Consideration was given first to standard methods for the control of corrosion through the application of hydrated lime, other alkaline salts, to boost pH values. Such a procedure, however, requires more or less constant attention and close chemical control to be really effective. Moreover, the cost of the operations, for a small company, is excessive and remoteness of the proper point of application at Dillsburg would make it more so. A search was made, therefore, for some easier solution of the problem, one which might be less exacting in control.

Limestone—Nature's Corrective

The suggestion was made by Wayne Laboratories that beds of limestone be prepared and the spring water passed through for treatment. In the absence of concrete information and technical data on such treatment no attempt was made to put such a plan in operation because lime treatment seemed the more positive and certain method.

At about this time an article appeared in WATER WORKS & SEWERAGE, under the name of Henry Ryon, describing the experimental work and full plant scale results at a state institution on Long Island, where crushed marble contact filters had been installed for the correction of a well water which has practically the same characteristics as that of the spring water at Dillsburg.

Using the Ryon data, from WATER WORKS AND SEWERAGE as a guide, an experimental unit (here sketched) was installed at Dillsburg. It was continuously operated for almost a year before determining on the plant scale design and practicability of the scheme, under winter conditions, life of the marble or limestone, and other important practical considerations, such as cloggage, difficulties and the like.

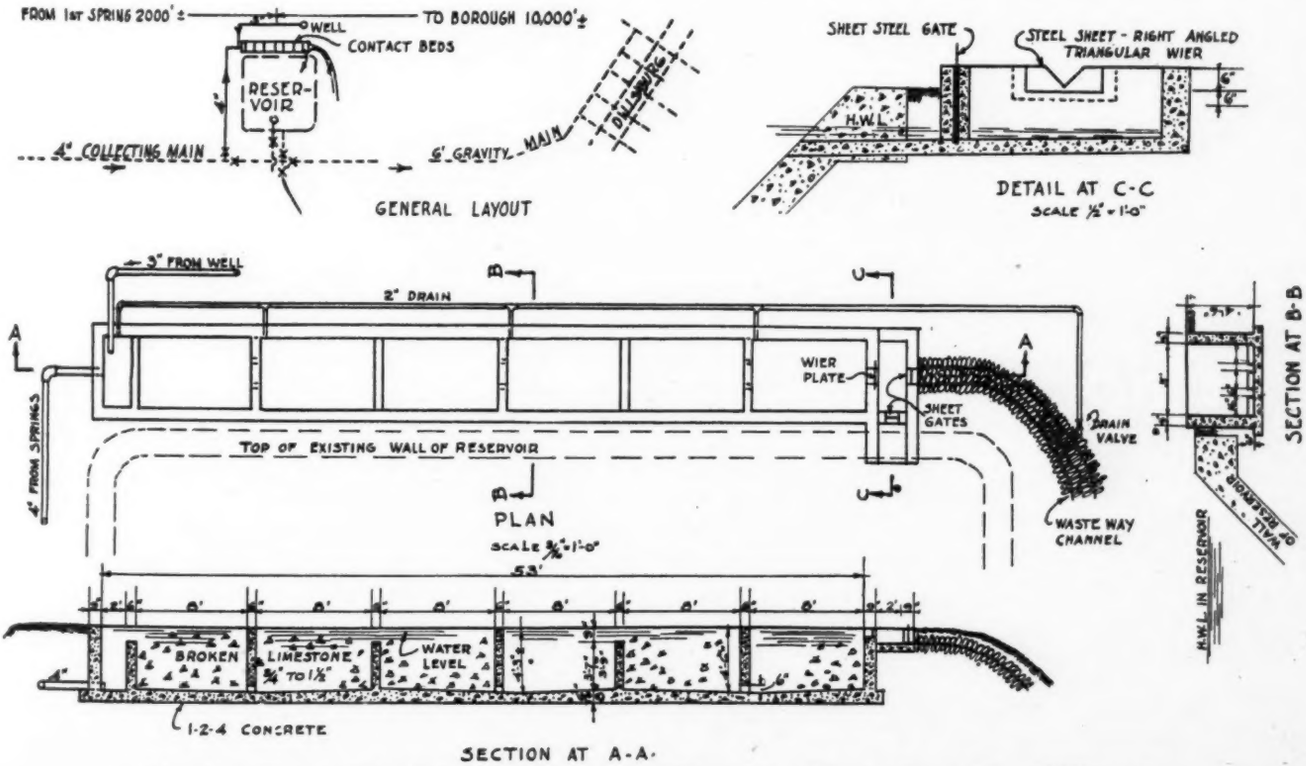
The incoming raw water and the outgoing treated water were metered as shown, using standard ⅝-inch service meters; the feed and discharge lines were of new galvanized iron pipe. The 50 gallon wooden barrel, and the terra-cotta pipes which serve as baffles for proper distribution through the tank, are filled with broken (high-calcium) limestone of about 1 inch size. The flow of water was regulated during most of the period at a rate of about 220 gals. per day, or slightly less than a pint per minute. It is interesting to note that this small amount of water was measured quite accurately (within a five per cent error) by the meters, as checked by volumetric determinations. The influent meter was operating under a head of only about one foot.

At this low rate of flow it is estimated that the water in its passage through the tank had a 2 hour contact, based on approximately 50 per cent voids in the limestone bed.

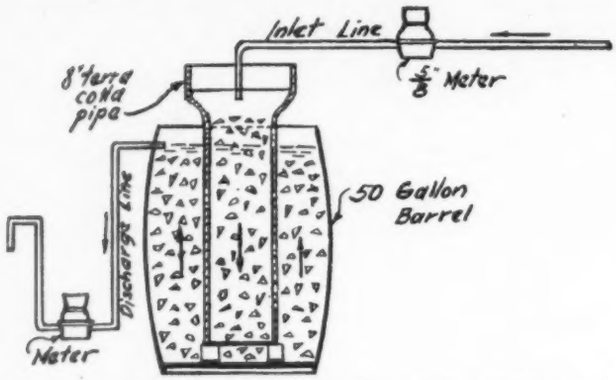
Observations and Deductions

At the end of the first six months' run, the inlet and outlet pipes and the meters were dismantled and examinad. The inlet pipe was already tuberculated and badly stained. The inlet meter likewise was heavily stained, but not tuberculated. The outlet pipe, on the other hand, showed no iron discoloration, and no tu-

*Taken from an article in WATER WORKS AND SEWERAGE.



Limestone Contact Beds Under Construction at Dillsburg, Pa. Capacity Better Than 50,000 g.p.d.



Experimental Calcium Carbonate Contact Bed Set Up and Operated in Corrosion Control Studies at Dillsburg, Pa.

berculation or pitting, but was covered with a soft and very light gray film. The outlet meter was not affected one way or the other.

The limestone at the top of the down-flow (inlet) compartment, was also excessively stained but, the stone surfaces at the outlet side were as clean apparently as on the day they were placed.

During this six-months period the rate of flow was uniform, it being controlled by means of a drilled coin union placed in the inlet line. Later a larger orifice was inserted and the rate tripled, with an immediate decrease in the efficiency of the treatment being noted.

Based on a number of determinations made in the field and in the laboratory (with results averaged), the experimental unit produced a very consistent effluent as follows:

	Raw	Treated
Hardness	12 p.p.m.	28
Alkalinity	8 p.p.m.	24
Carbon dioxide	20	2
pH	5.4	7.4

The practical benefits of a non-corrosive water have recently been well demonstrated by the New England Water Works Association, in its report on Pipe Line Friction Coefficients, which emphasizes the inter-relationship between calcium carbonate, alkalinity, and CO_2 content, and the value of pH of the supply as an index of rate of capacity loss. The figures given above seem to be in agreement with the findings of the committee.

As a result of this experimental work, a full-scale plant (see sketch) has been designed, using the same principles of treatment, and is now being installed at Dillsburg.

Additional Observations

Further evidence of the efficacy of this type of treatment, for control of corrosion, has been secured in another and muchl arger community. The supply is essentially the same as that at Dillsburg.

At the present time complaints of "red water" are frequent occurrences. This condition existed in the home of the local superintendent, who, on his own initiative, removed the iron service lines in his home and installed copper service pipes throughout, as well as a copper hot water tank.

In less than a month after the copper pipes were installed, the iron stains formerly present on the plumbing fixtures disappeared, and the typical green stains of copper became noticeable. To these the writer's attention was directed at about the time that the first definite data had been secured at Dillsburg.

As a further experiment, therefore, a 50 gallon galvanized iron hot water tank was secured, filled with ½-inch broken limestone, and installed on the service line into the superintendent's home. An immedate improvement followed. The copper stains disappeared from the fixtures and, after six months' operation, have not again re-appeared. Because of the great irregularity of flow of water in this as in other private homes, the pH and other characteristics of the treated water have not been so uniform as were those of the Dillsburg unit, which was operated at a constant rate of flow. However, at no time did the pH of the limestone-passivated tap water fall below 7.0 and has been usually higher.

It is recognized that additional tests and further demonstrations are necessary before final conclusions are justified on this simplified type of treatment. The results to date, however, have definitely surpassed expectations and the method is attractive even if some supplementary chemical treatment proves advisable at a later date.

Maximum Flow Gage for Sewers*

The accompanying sketch pictures the type of maximum flow gage, which has been installed in five manholes in the village of Shorewood in Milwaukee County, Wisconsin.

Metcalf and Eddy, in "American Sewerage Practice" (Vol. 1), under Maximum Flow Gages, describe a device that is substantially a stick with small vials attached along its length and inserted into a perforated pipe. The level of the mouth of the highest vial found full indicates the height to which the sewage has risen in the manhole. This design, however, has its disadvantages. First, the vials are breakable and entail considerable trouble in replacing. Second, it can not be used where the velocity exceeds eight feet per second.

The improvements in the Shorewood installation are:

First: It is cheap—the entire gage, made by a tinner and ready to install, costs very little.

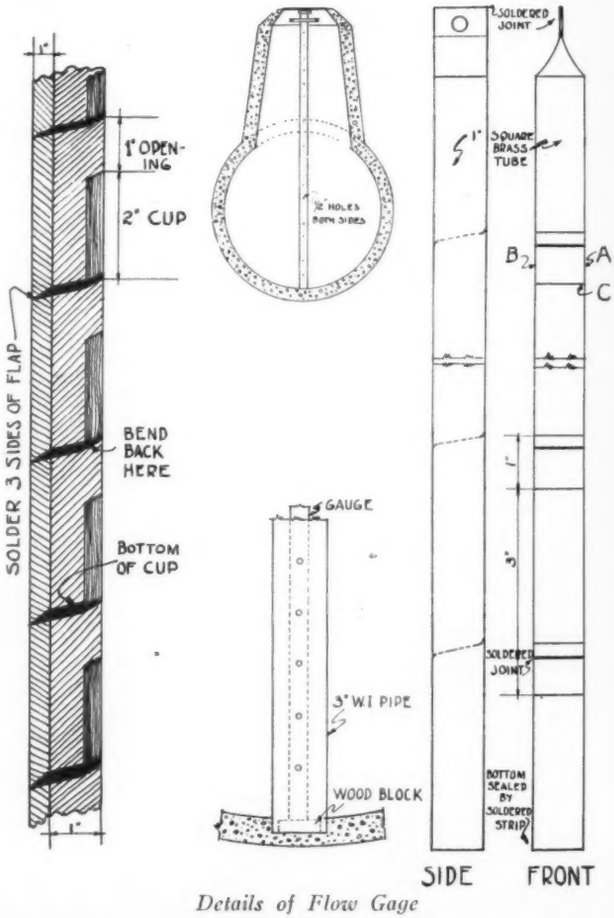
Second: It is not breakable and may be used in sewers regardless of velocity. Being made of brass or copper it is immune to corrosion.

A brief description may be helpful.—This gage is made of one inch (square) brass tubing, with one face (C on sketch) cut through at predetermined spacings. In the Shorewood design it is three inches. Then the corners are ground off on a power grinder to make edges A and B. The resulting flap is bent back and soldered in place to form the bottom of the pocket above. The block of wood is to raise the gage to the elevation of the invert of the sewer. The spacing of the pockets and the width of the mouths may be varied to suit circumstances. A perforated 2 in. W.I. pipe protects the gage.

In practice the gage has proven reliable and has served satisfactorily through several storms when the sewers were surcharged.

Credit for this design belongs to George Dewey Simms, Assistant Village Engineer, Shorewood, Wis.

*Contributed by Julius Lucoff, Milwaukee, Wis.



Details of Flow Gage

CORROSION CONTROL BY DEAERATION

By SHEPPARD T. POWELL[1] and H. E. BACON[2]
Baltimore, Maryland

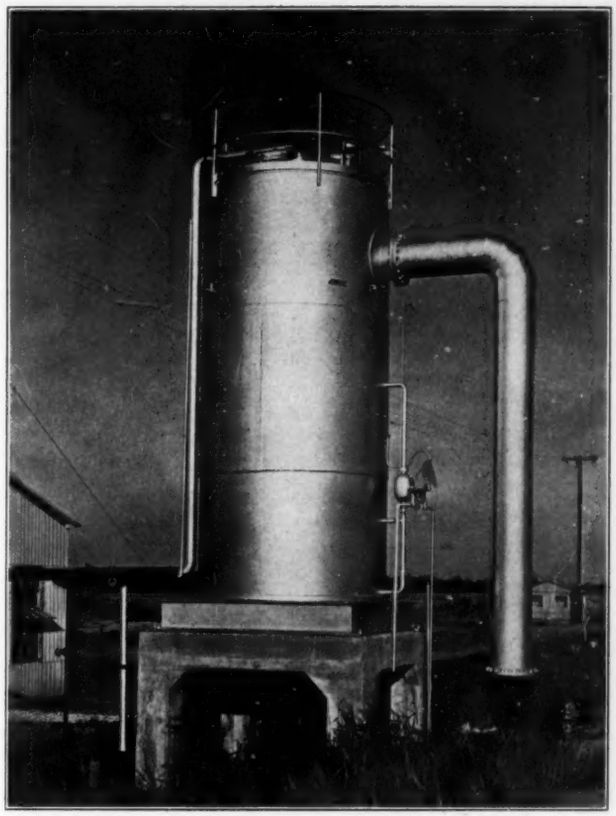
All branches of engineering in which the handling of water is involved have found the corrosion of ferrous materials to be a major problem. Preventive methods have been developed as more detailed knowledge of the corrosion process has been gained. At the present time the mechanism of corrosion under various conditions has been the subject of considerable experimental and theoretical study and is fairly well understood. It is well established that the attack of water upon iron results in a concentration of hydrogen ions at the surface of the metal, which stops the corrosion process under the conditions usually encountered in ordinary water for domestic or industrial use. Dissolved oxygen in the water reacts with this protective hydrogen, which is thus removed, and in consequence permits the attack on the metal to continue. Speller lists the oxygen concentration as first in importance among the factors in corrosion by water in the neutral zone.

Protective Coatings

Many methods of corrosion control seek to prevent the water from coming in contact with the metal, by interposing protective layers of various kinds. These may be deposited chemically, as in the case of films which confer passivity on the metal, or scales formed from minerals in the water. Protective coatings and linings are also applied in the form of various paints and cements. Efforts to prevent the corrosion of water mains are generally effected in this way, and when carried out properly such treatment is successful.

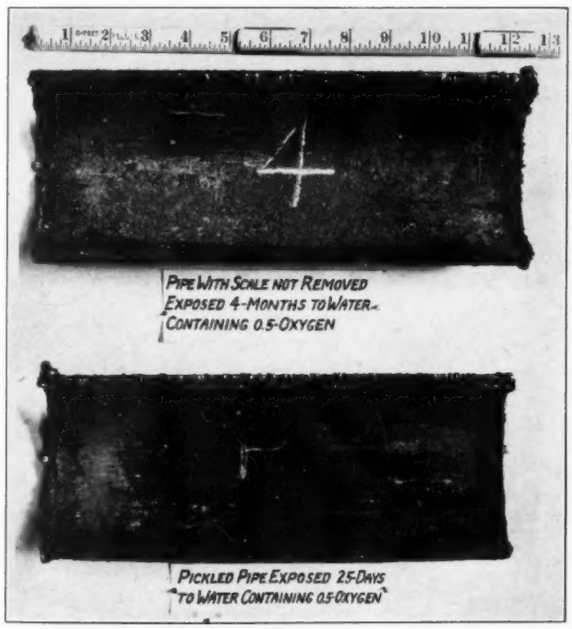
Oxygen Removal

Since dissolved oxygen is generally necessary for the continuous attack of water upon ferrous materials, considerable attention has been given to removal of this gas from water. It is a well-established fact that corrosion of pipes carrying hot or cold water can be enormously curtailed merely by removal of dissolved oxygen from the water. Such treatment is regarded as imperative for boiler feedwater and is accomplished by elevating the temperature, to reduce the solubility of oxygen, and venting the gas which is evolved. Chemical reducing agents are frequently used to complete the deaeration of the water. Hot water heaters have been used to a limited extent for partial deaeration of hot water used in large buildings, and cold water has been deactivated by apparatus which provided for removal of oxygen by contact with scrap iron. However, removal of dissolved oxygen has not been widely practiced except for the deaeration of boiler feedwater.



The Completed Deaerator. Capacity 4 M.G.D. Vacuum 28 to 28.5 Inches. (For Details and Dimensions, See Sketch)

*From WATER WORKS AND SEWERAGE, April, 1937.
[1]Consulting Chemical Engineer and [2]Associate.



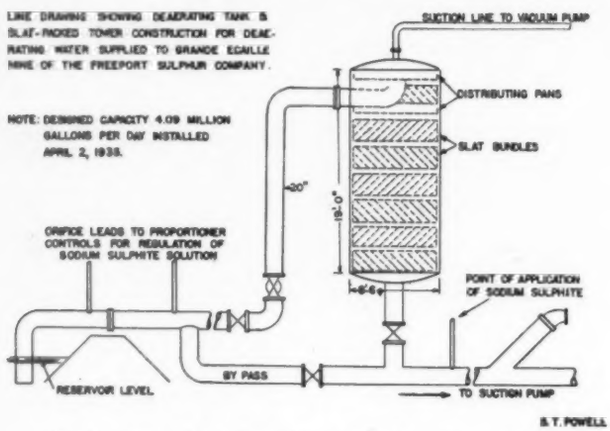
A Dual Demonstration in Corrosion Control. (Below) The Non-Corrosiveness of Deoxygenated Water on Bare Smooth Walled Steel Pipe. (Above) The Effect of Mill-Scale in Increasing Corrosion, Even in the Practical Absence of Dissolved Oxygen and pH Values Approaching 8.2

Freeport Sulphur Co.'s Problem

The Freeport Sulphur Comany, operating mines in Louisiana and Texas, has encountered the problem of corrosion in connection with its water supply system, and the corrective methods adopted have attracted considerable interest. This company has developed the sulphur resources in the Mississippi delta below New Orleans, with a mine located at Grande Ecaille, Louisiana. Since the sulphur mining process requires large volumes of hot water and it is also necessary to generate considerable steam, an adequate water supply is essential to this industry. This was obtained by establishing a reservoir and pumping station at Port Sulphur, located on the Mississippi river nine miles from the mine. The reservoir water is pumped from here to the property through an uncoated steel pipe. This line is welded and is carried on piles and passes under water only at bayou crossings.

Provision was made for supplying 4,090,000 gallons per day, which was required for operation at the desired rate. However, in four months the carrying capacity of the line decreased nearly 25 per cent due to corrosion of the pipes, which likewise seriously threatened the destruction of the pipe. An examination of the pipe revealed excessive tuberculation, which accounted for the marked rise in the coefficient of friction and consequent depreciated carrying capacity of the line, and increased pumping costs.

Consideration was given to lime treatment to inhibit aggressivity of the water, involving the possibility of producing on the pipe walls a thin protective coating of calcium carbonate. The river water, however, was not susceptible to the precipitation of calcium carbonate by this treatment, because the pH of the settled river water was approximately 8.0, no bicarbonate alkalinity being present most of the time. Sodium silicate was applied in the hope that a silicate scale could be deposited, but evidence


LINE DRAWING SHOWING DEAERATING TANK & SLAT-PACKED TOWER CONSTRUCTION FOR DEAERATING WATER SUPPLIED TO GRANDE ECAILLE MINE OF THE FREEPORT SULPHUR COMPANY.
NOTE: DESIGNED CAPACITY 4.09 MILLION GALLONS PER DAY INSTALLED APRIL 2, 1935.
SUCTION LINE TO VACUUM PUMP
DISTRIBUTING PANS
SLAT BUNDLES
20"
18'-0"
6'-6"
ORIFICE LEADS TO PROPORTIONER CONTROLS FOR REGULATION OF SODIUM SULPHITE SOLUTION
POINT OF APPLICATION OF SODIUM SULPHITE
RESERVOIR LEVEL
BY PASS
TO SUCTION PUMP
S.T. POWELL

Section Through Deaerator and Piping Arrangement

indicated that corrosion continued, or was retarded so little that the treatment was not justified. Further, there was definite evidence that silicate scale was developing in the boilers, and, fearful of consequences, the immediate termination of the silica treatment was determined on.

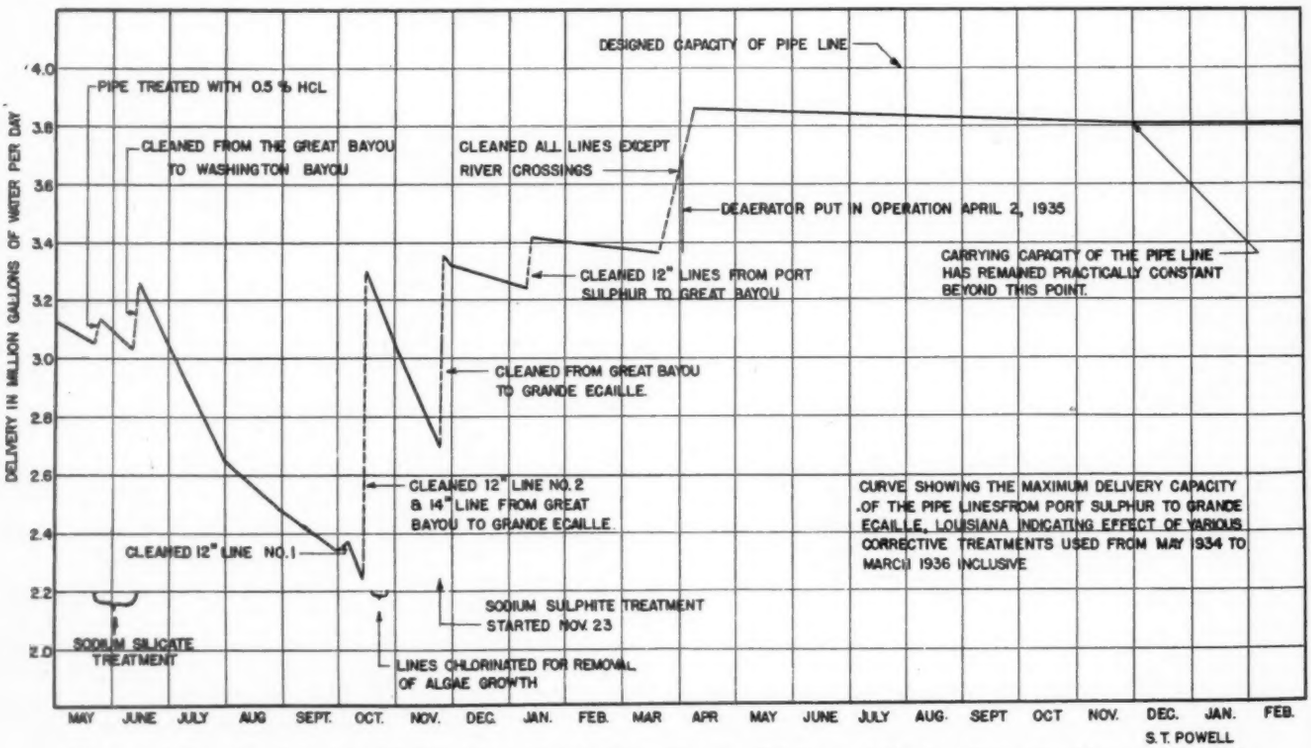
Oxygen Removal Turned to

These experiences led finally to consideration of deaeration of the supply as that treatment which would insure a most overall satisfactory solution of the problem. The oxygen present in the water varied between 6 and 10 parts per million, and exceeded the saturation value at times because of the presence of prolific growths of micro-organisms. Deaeration with sodium sulphite was undertaken experimentally, and almost immediately a reduction was noted in the rate at which the capactiy of the line was decreasing. The expense of chemical deaeration would have been prohibitive, however; and, having served to demonstrate the efficiency of deoxygenation, it was not considered as a permanent treatment. In view of the proven benefits of dissolved oxygen removal, steps were taken to design equipment for mechanically deaerating the water by passing it through an evacuated chamber.

The only previous large-scale application of the deaeration process had been at Coolgardie, Australia, where 6,000,000 gallons of water per day are deaerated to protect a 350-mile pipe line. Inquiries directed to the officials in charge of this latter installation brought the information that excellent results were being obtained, which confirmed statements appearing somewhat earlier in the technical literature. As a result of the investigation and the favorable record of the Australian plant, a cold water deaerator was designed. This consisted of a tower, into the top of which water was to be introduced in the form of a relatively fine spray, dropping into a collecting chamber at the bottom of the unit, from which it could be pumped into the pipe line. The apparatus was to be maintained under a specified vacuum and the gases, flashed from the water, removed by the vacuum pump. An adequate seal was designed so that the desired vacuum could be maintained. Calculations were made to determine the operating characteristics of various designs and the required vacuum pump capacities and cost factors involved in installation and operation.

On the basis of this information a small pilot plant, having a capacity of 100 gallons per minute, was built. This equipment differed from the earlier designed unit in that the tower was packed with wooden slats over which the water trickled in thin films from which gases were readily released. Experiments were made to determine the oxygen removal resulting when the water was dropped from various heights and when different degrees of vacuum were maintained. These tests showed that approximately 95 per cent oxygen removal from the water was effected [0.33 p.p.m residual oxygen] when the deaerating chamber was under a vacuum of 28.5 inches. The curve of oxygen removal becomes almost horizontal at this vacuum and further reduction in pressure requires rapidly increasing pump capacity because of the much larger volume of the rarified gases under the lower pressure. It was determined that the remaining 5 per cent of dissolved oxygen could, therefore, be removed most practicably and economically by means of the deoxygenating sodium sulphite than by extending the mechanical process. The type of deaerating unit constructed as the pilot plant was a much less expensive form of construction than the Australian apparatus, and, since excellent results were obtained, it was used as the pattern in designing the full-scale plant.

Water deaerated by the pilot plant was passed through a 4-inch discharge line for a period of three months. At the end of this period the line was inspected and sections of the pipe were cut longitudinally. No tuberculation was found, and by comparison with control specimens carrying undeaerated water it was obvious that corrosion was almost entirely inhibited. In each case portions of pipe from which the mill-scale has been removed by pickling were inserted in the line. This was done in order to evaluate the harmful effect of mill-scale on past operation. The pipe which contained mill-scale was much more seriously attacked by water with normal oxygen content than was the pickled (cleaned) speci-

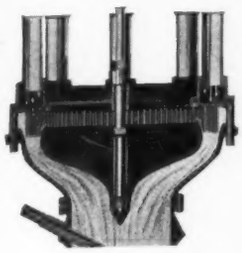

DESIGNED CAPACITY OF PIPE LINE
PIPE TREATED WITH 0.5 % HCL
CLEANED FROM THE GREAT BAYOU TO WASHINGTON BAYOU
CLEANED ALL LINES EXCEPT RIVER CROSSINGS
DEAERATOR PUT IN OPERATION APRIL 2, 1935
CLEANED 12" LINES FROM PORT SULPHUR TO GREAT BAYOU
CARRYING CAPACITY OF THE PIPE LINE HAS REMAINED PRACTICALLY CONSTANT BEYOND THIS POINT.
CLEANED FROM GREAT BAYOU TO GRANDE ECAILLE
CLEANED 12" LINE NO. 2 & 14" LINE FROM GREAT BAYOU TO GRANDE ECAILLE
CURVE SHOWING THE MAXIMUM DELIVERY CAPACITY OF THE PIPE LINES FROM PORT SULPHUR TO GRANDE ECAILLE, LOUISIANA INDICATING EFFECT OF VARIOUS CORRECTIVE TREATMENTS USED FROM MAY 1934 TO MARCH 1936 INCLUSIVE
CLEANED 12" LINE NO. 1
SODIUM SULPHITE TREATMENT STARTED NOV. 23
SODIUM SILICATE TREATMENT
LINES CHLORINATED FOR REMOVAL OF ALGAE GROWTH
DELIVERY IN MILLION GALLONS OF WATER PER DAY
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB
S.T. POWELL

History of Carrying Capacity of 9-Mile Water Supply Main Showing Efficiency of Various Corrective Measures Applied

VOGT MFG. CO.

INCORPORATED

FACTORY MAIL ADDRESS P. O. BOX 1122, LOUISVILLE, KY.

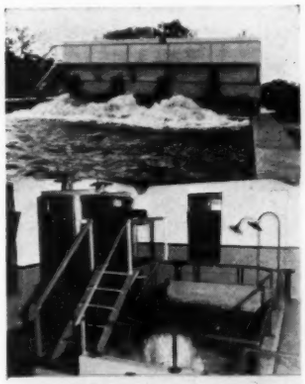


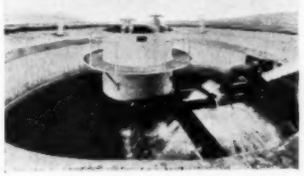
Cross section of Aer-O-Mix aspirator tube head and throat.

Products— "AER - O - MIX," Aerators, Aerator-mixers, Aspirators, Gas Diffusers, Carbonators, Recarbonators, Chemical Mixers.

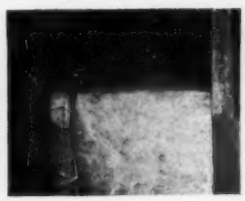
"Smog Suction" AERO-MIX

For outside or inside installation. Non - freezing. Gravity (head loss) type; Rotary (motor-driven — no head loss) type; Pressure type; Self–contained, closed unit type. For use in water treatment plants; sewage treatment plants; industrial waste treament, etc. A six-point method involving diffusion, compression, retention, expulsion, surface contact, agglomeration.



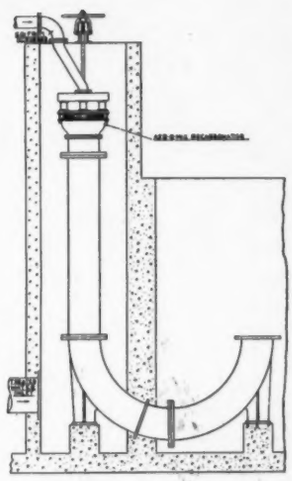


Pictured at right are photographs of (1) Rotary Aer-O-Mix with submerged discharge; (2) looking down on surface of carbonation chamber with submerged discharge Aer-O-Mix carbonator. Below, sketch showing Rotary Aer-O-Mix carbonator for drawing gas direct from scrubber and effecting complete diffusion. At left, views of inside and outside gravity Aer–O-Mix installations.



Total capacities of Aer-O-Mix installations now aggregate more than 1/3 Billion gallons per 24 hours.

Write for information and literature.



VOGT BROTHERS MFG. CO.

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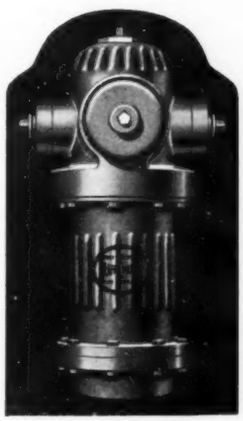

Products—Fire Hydrants, Water Works Gate Valves, Tapping Sleeves, Tapping Valves, Valve Boxes, Municipal Castings.

Above: Vogt Brothers' Revolving, Removable, Replaceable Head Fire Hydrant, showing sectional "Traffic Model" Standpipe; also made with "unit" one-piece standpipe. Right: Sectional view, showing simplicity of construction—Standard A. W. W. A. Specifications.

All Vogt Brothers' Gate Valves are in strict accordance with Standard A. W. W. A. Specifications. In addition to the products illustrated here, we also make Spigot Connection Valves, Flanged Valves, Valves for horizontal operation, with gears, handwheels, etc. **All products are made complete in our own Foundries and Shops and prompt shipment can be made on all items.**

Write for literature and prices.

Wedge Type Tapping Sleeves for leaded connection

Bolted Type Tapping Sleeves for use with bolted type tapping valves.

Double Hub End Gate Valve

Standard Leaded Type Tapping Valve

men. With deaerated water, however, the corrosion was very slight, even in the presence of mill-scale, although it was apparent that pickling had been of some benefit in this case also.

Plant Scale Installation

Observations on the pilot plant and calculations for a full-scale unit were so encouraging that a large deaerator was constructed, capable of treating the entire supply of 4,000,000 gallons per day, for which the pipe line was designed. The deaerating apparatus is illustrated in the accompanying sketch and photograph. It will be noted that the vacuum maintained is sufficient to draw the water from the reservoir into the deaerator. The water is distributed over the slat bundles by two perforated pans and is discharged to the suction of the pump feeding the pipe line. Sodium sulphite is applied at a point between the deaerator and the pumps. This chemical is fed by means of a Cochrane proportioner. The water is pumped through the 9-mile line by three 10x8-inch HYC two-stage Allis-Chalmers centrifugal pumps. A Worthington 18x7-inch dry vacuum pump, with an overall efficiency of 39 per cent, is used for maintaining a vacuum of 28 to 28.5 inches in the deaerating tower.

Results of Treatments

The result of this treatment and the entire history of the pipe line are strikingly illustrated in the chart picturing carrying capacities. It will be noted that since the deaerator was put into operation in April, 1935, decrease in carrying capacity has occurred at a very slow rate, and at the present time this curve has become practically horizontal. The pipe line has been inspected at several points and it is apparent that tuberculation has been almost entirely stopped. It is therefore believed that deaeration of the cold water is an entirely satisfactory solution to the very serious problem with which this company was faced. Moreover, this installation has afforded a practical demonstration of the feasibility of mechanically deaerating even large quantities of cold water where the protection of pipes of ferrous material is desired.

Acknowledgment.—We wish to express our appreciation of the assistance and co-operation of W. T. Lundy, vice-president and general manager, and Homer S. Burns, vice-president, of the Freeport Sulphur Company, which have made the project a success and this article possible.

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.13	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

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CHEMICALS FOR WATER AND SEWAGE TREATMENT

22 E. 40th St., New York **Cables: Trufabest, N. Y.**

PRODUCTS:
Copperas, Ferrous Sulphate, Iron Sulphate, Copper Sulphate.

Faesy & Besthoff, Inc.
CHEMICALS

Write for samples and technical information.

CHLORINATED-COPPERAS

(Amongst the most modern of the coagulants are the ferric salts. The most economical source as a ferric coagulant is ferrous-sulphate oxydized with liquid chlorine—i.e., "Chlorinated-Copperas".)

IN SEWERAGE TREATMENT

For Sewerage Treatment, we wish to call your attention to a well-known authority* and his published reasons* for selecting Chlorinated-Copperas, as a coagulant.

1—Chlorinated-Copperas proved to be the cheapest coagulant to produce desired results under existing conditions.

2—The reaction between Copperas and Chlorine proved to be practically instantaneous and required no close control or complicated apparatus—a slight excess of Chlorine being added along with the Copperas for sterilization.

3—Chlorine and Copperas were both easily applied through commonplace equipment and did not present any corrosion problems beyond those experienced in water purification.

4—Chlorinated-Copperas is desirable as a coagulant because of ease of handling, low cost, and ease of application.

IN WATER TREATMENT

Summarizing the experiences with Chlorinated-Copperas in a large city another well-known and proficient manager* states in a published article* the following conclusions:

1—That it is an excellent cold water coagulant.

2—That it has reduced operating costs.

3—That it produces benefits, with no unfavorable results.

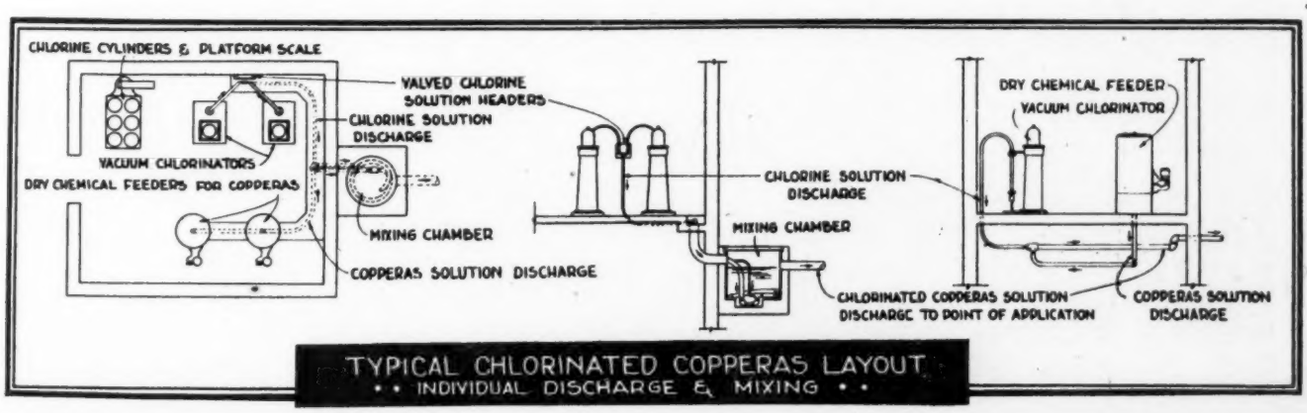
*(References to articles and authors' names available upon request).

KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

Root troubles in sewers can be eliminated by the use of Copper Sulphate. Cities and towns have used copper sulphate for this purpose for several years. By throwing in the copper sulphate crystals into choked sewers, while at least some sewage is still flowing, a sufficient concentration of the poison kills the "feeder" stem and the root mass breaks the dead stem which has lost its toughness. Down sewer go the root balls to its outlet.

ALGAE CONTROL

Copper Sulphate has long been recommended by leading water works engineers, when slime, scum or other effects of algae and undesirable micro-organisms give trouble. Easiest algicide to use, no special equipment or training required.



TYPICAL CHLORINATED COPPERAS LAYOUT
•• INDIVIDUAL DISCHARGE & MIXING ••

WATER SOFTENING*

by CHAS. P. HOOVER
Columbus, Ohio

The consumer judges water to be hard if much soap is required to produce a lather, and soft if it lathers freely. The hardness of most water supplies is due to four compounds which are held in solution. These compounds are:

1. Calcium bicarbonate (solution of limestone, $CaCO_3$, in waters containing carbon dioxide, CO_2).
2. Magnesium bicarbonate (solution of magnesite, $MgCO_3$, in waters containing carbon dioxide, CO_2).
3. Calcium sulphate (in the form, $CaSO_4.2H_2O$, is known as gypsum).
4. Magnesium sulphate (in the form, $MgSO_4.7H_2O$, is known as epsom salts).

As long as any of these compounds or a combination of them are present in a water supply it is hard.

Chlorides and nitrates of calcium and magnesium are sometimes present.

Calcium and magnesium bicarbonates were formerly designated as temporary hardness, but are now termed carbonate hardness.

Calcium and magnesium sulphates, chlorides, and nitrates were formerly designated as permanent hardness or incrustants, but are now usually called non-carbonate hardness.

Water softening processes remove objectionable iron compounds and manganese as well as hardness.

In general terms, hard water is made soft by a treatment which changes calcium and magnesium compounds from a soluble to an insoluble form, and then by removing the insoluble compounds by sedimentation and filtration, or by an exchange process, which consists in replacing the calcium and magnesium with sodium. The first process is known as the chemical, or lime-soda process, and the second, the zeolite process.

[Elsewhere in this issue appears a map of the United States which reveals the average hardness of public water supplies of important American municipalities, of each State.—*Ed.*]

History

The art of water softening with lime dates back to the year 1766 when Cavendish discovered that the addition of lime to natural water caused a deposition of the carbonates of calcium and magnesium. The proposal to use lime for softening hard water on a plant scale was advanced by Thomas Henry in England about 1800, but it was not until 1841 that water softening on a large scale was developed by Dr. Thomas Clark of Aberdeen, Scotland. He patented the process of adding lime to water to precipitate earthy carbonates held in solution by carbonic acid.

Winnipeg, Canada, built the first municipal plant in 1901. In 1903, the first municipal plant in the United States was built at Oberlin, Ohio.

In 1908, water softening on a larger scale than had hitherto been tried was undertaken at Columbus, Ohio, when a plant having a capacity of thirty million gallons per day (now 50 m.g.d.) was constructed.

For years the advantages of water softening were offset to a certain extent by disadvantages. Difficulties arose in operating sand filters on account of incrustation of the sand with calcium carbonate. Water mains, service pipes and meters became clogged with heavy deposits. When water contained an excess of causticity it was unpalatable. The recarbonation process developed by Archbutt and Deeley in the latter part of the last century, was employed at several plants in England for the purpose of overcoming all the above difficulties, but its first employment in this country, on a successful plant scale, was in 1921 at Defiance, Ohio. Since that time practically all water softening plants have been equipped with recarbonation devices.

The chemistry of water softening is now well understood, and an exact prediction of the results to be obtained can be made. Improvements in design and equipment for applying chemicals and removing sludge all tend toward simplifying operation. As a result of these improvements there has been a decided trend toward some degree of water softening by municipalities throughout the United States. Industry has gone forward with water softening to a far greater extent because of proven economies in processes, materials and equipment where soft water is made available.

Economic Aspects of Water Softening

The water supply in a large number of cities and villages should be softened because:

1. Hard water destroys soap; makes household work more difficult; has a bad effect on clothes washed in it, on plumbing, heating systems, boiler tubes and shells; and is unsuitable for many industries.
2. Softening at a central source of supply rather than in thousands of homes is economically sound.

It is cheaper to pay a reasonable additional charge for centralized softening than to accept a hard supply, a portion of which must be softened in the home. All of us, whether we

*Ecerpts from "Water Supply and Treatment"—written by Mr. Hoover and published by the National Lime Association.

America's Most Attractive Water Works Plant (WATER WORKS AND SEWERAGE *Contest*—1935) *and the Newest of American Softening Plants of Important Size*

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A complete line of Water Conditioning Equipment, including: Manually operated and fully automatic downflow and upflow zeolite water softeners; porous and non-porous zeolites; hot process and cold process intermittent and continuous lime-soda water softeners; internal boiler feedwater treatment; pressure and gravity filters; taste, color and odor removing equipment; activated carbon filters; coagulant and corrective chemical feeds; iron and manganese removal equipment; continuous blowoff equipment; anti-corrosion equipment; carbon-dioxide recorders, etc.

Zeolite Water Softeners

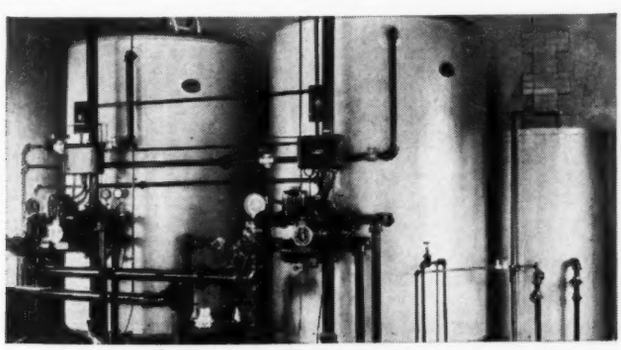
Zeolite water softeners are coming into widespread use for softening municipal water supplies, for which purpose they offer a number of distinct advantages. Prominent among these are their simplicity; flexibility, ease of operation; positiveness of results; ability to operate on either a gravity or pressure system; low installation and operating costs; and freedom from sludge disposal problems.

As a zeolite water softening plant may consist of one or more units, a plant, when installed, need not be larger than is needed for present requirements, as additional units may later be added to take care of an increased water demand.

Municipal zeolite water softening plants may be operated so as to secure effluents of any desired degree of hardness. They may also be employed with iron or manganese bearing well waters, as they remove iron or manganese simultaneously with and in the same manner as they remove hardness.

Automatic Zeolite Water Softeners

By a system of electrical controls, completely automatic operation of a zeolite water softening plant is secured. These controls may be applied to either a gravity or pressure type of plant and may also be applied to existing installation, thus making their operation completely automatic.

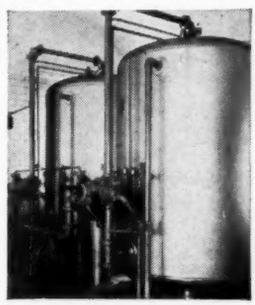


Municipal Automatic Zeolite Water Softening Plant at Elmore, Ohio

The automatic zeolite water softeners have proven especially popular in municipal water softening plants and the great majority of the newer municipal plants are of the completely automatic type. Write for full information.

Zeolites

All types of zeolites, including ZEO-DUR, the standard greensand base zeolite; SUPER-ZEO-DUR, the high capacity greensand base zeolite; DECALSO, the high capacity manufactured zeolite; and MANGANESE PERMUTIT for iron and manganese removal. Also ZEO-KARB, the new non-siliceous zeolite that may be regenerated through sodium or hydrogen cycles. Write for special bulletin.



Municipal Manganese Zeolite Iron Removal Filters at East Lansing, Michigan

Water Filters

Built in a wide range of sizes and types to cover all requirements. Steel shell, pressure filters of the vertical type obtainable in all sizes up to 10 feet in diameter. Steel shell, pressure filters of the horizontal type are obtainable in a diameter of 8 feet and up to 25 feet in length. Gravity type filters of wood or concrete construction built to suit requirements.

Chemical Feeds

All types of chemical feeds, constant or proportionating, for feeding sulphate of alumina or other coagulants; soda ash; lime; silicate of soda; etc. These include the following types: gravity; pressure solution; dry; and electro-chemical.

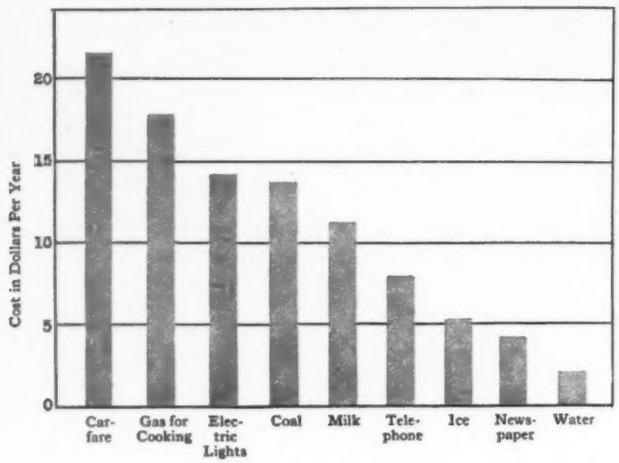
Control Unit of Electro-Chemical Feed — double drum type for feeding two chemicals—adjusted separately and instantly by the finger tip.

The electro-chemical feed, illustrated above, is particularly applicable where accuracy of feeding is essential, in addition to which it is of a simple and rugged construction.

Partial List of Permutit Bulletins

1. Water Softening by Zeolites as Used in Municipalities.
2. Experiences in Zeolite Softening.
3. An Automatic Softening Plant for Utica's Water Supply.
4. Pressure Zeolite Water Softening at Elmore, Ohio.
5. Zeolite Water Softening Plant Built with FERA Funds.
6. Zeolites: Mining, Processing, Manufacture and Uses.
7. Water Filters and Filtration Equipment.

The above list represents but a few of our bulletins on special subjects, any of which may be obtained free on request. Kindly order by name.



Cost Per Capita Per Year for Domestic Services (Family of Five)

know it or not, soften some water each day, for it is necessary to use soft water to keep clean.

All public water supplies contain some hardness and that portion of the water in which soap is used must be softened to be effective. Soap has very little cleansing action until it lathers and it will not lather until the hardness salts in the water have been neutralized by it.

Aside from the objections of the precipitated soap curd, the extravagance of removing hardness with soap can be appreciated when it is realized that a pound of lime costing approximately one-half cent will neutralize as much hardness as 20 pounds of soap costing approximately $3.00.

Soap Losses Determined Experimentally

The amount of soap consumed and the quantity of water used for household processes, laundering, dish-washing, cleaning, washbowl activities, and bathing, was carefully measured for a period of one week, and calculated for a year.[1] Two kinds of water were used, each for one week: (1) Scioto River water which was filtered and sterilized but not softened. The hardness was 270 parts per million (16 grains per gallon). It was delivered in 10-gallon bottles to the home where the experiments were made. (2) Softened water as delivered to consumers. The hardness averaged about 80 parts per million (4.7 grains per gallon). In the home where the experiments were made there were five people, three adults and two children. Ivory soap in bar and flake form was used, the former costing 21 cents per pound and the latter 31 cents. The laundering was done in a vacuum type electric washer, the weight of the clothes averaging 29 pounds per washing.

Water-works records show that this family used the average quantity of water, about 30 gallons per day per capita. Their bill amounted to 75 cents per month. The soap was dried and weighed before and after it was used, so that the difference in weight would represent the weight actually used. The results for the week figured to one year show:

1. That this family used 281 gallons of water a week for ordinary household cleaning, divided as follows: Laundry, 15 gallons; dish-washing, 73 gallons; cleaning, 4 gallons; bathing, 136 gallons; and washing of hands, 53 gallons.
2. That approximately 11.46 pounds of soap were used per week with unsoftened water, or a total of 596 pounds per year.
3. That approximately 3.7 pounds of soap were used per week with Columbus city softened water, or a total of 192.5 pounds per year.
4. That softened water saved this family 403.5 pounds of soap per year.
5. That this soap, valued at 20 cents per pound, represented a saving of $80.70 per year and figured at 12 cents a pound, the price of cheaper laundry soaps, represented a saving of $48.42.
6. That this consumer could afford to pay five or six times as much for softened as for unsoftened water.

The investigation also disclosed the following facts:

1. One-half again as much time was needed to launder clothes in the unsoftened as with the softened water.
2. The cleanliness of clothes washed in the unsoftened water was not entirely satisfactory. Several very soiled pieces had to be rewashed and all of the clothes had to be re-rinsed.
3. The general appearance of the clothes was unsatisfactory.

These figures may be high for the average family but they are fairly representative for a family of five living in moderate circumstances. There are 55,033 domestic services or consumers in Columbus, Ohio. Applying the above figures, if each one saves $48.42, the total saving would amount to $2,664,697.86. If this figure is divided by two because of the possible use of cheaper compounds to "break" the water, the saving would be $1,332,348.93. This amount is about eight or ten times the cost of chemical softening.

[1]Thesis presented for the degree of Master of Science by Miss Pauline Snyder, Ohio State University, 1927.

Relations of Soap Wastage to Quantity and Type of Water

The above experiment demonstrated that 8 gallons of water per day per person were used for household processes. This quantity was probably not all completely softened by soap. Other workers have made the following estimates of water completely softened per capita per day:

	Gallons
Foulk[2]	0.9
Report of Special Committee for Madison, Wis.	1.7
City of St. Louis[3]	1.0
Average	1.2

The amount of soap required to reduce the hardness of 1,000 gallons of water, one part per million, has been determined as being 0.2 of a pound (Foulk's formula: Pounds of soap consumed per 1,000 gallons $= 2 + 0.2H$).

Based on these assumptions, the loss per family of five using water of varying degrees of hardness is shown in the following table:

SOAP WASTAGE AND COST WHEN USING WATER HAVING HARDNESS VARYING FROM 150 TO 500 PARTS PER MILLION

Raw water hardness p.p.m	Hardness removed by softening	Hardness reduced to	Loss lbs. of soap per family of five per yr.	Loss per family of five per year*
150	65	85	28.5	$3.40
200	115	85	50.0	6.00
250	165	85	72.5	8.70
300	215	85	94.0	11.30
350	265	85	116.0	13.90
400	315	85	138.0	16.55
450	365	85	160.0	19.20
500	415	85	182.0	21.85

*Soap at 12 cents per pound.

Actual Survey of Retail Soap Sales

The economic effects of quality of water, with special reference to soap consumption in the home, were demonstrated by H. W. Hudson[4] in a field survey of retail soap sales in four cities of the middle west: Superior, Wisconsin, and Bloomington, Champaign-Urbana, and Chicago Heights, Illinois. A canvass of all retail stores selling soap in these cities was made by a personal investigator who compiled a complete record of soap sales. The soap sales and per capita soap consumption with different types of water are shown in the following tables:

TOTAL SOAP SALES IN FOUR CITIES

City	Annual soap sales, pounds	Annual soap sales, dollars
Superior, Wisconsin	1,530,314	$196,133
Bloomington, Illinois	1,517,658	215,528
Champaign-Urbana, Illinois	2,093,881	307,732
Chicago Heights, Illinois	1,009,503	159,910

PER CAPITA SOAP CONSUMPTION WITH DIFFERENT TYPES OF WATER

City	Total hardness of water supply p.p.m.	Annual per capita soap consumption pounds	Annual cost of soap per capita dollars
Superior, Wisconsin	45	29.23	$3.75
Bloomington, Illinois	70	32.13	4.48
Champaign-Urbana, Illinois	298	39.89	5.93
Chicago Heights, Illinois	555	45.78	7.50

[2]Geological Survey of Ohio, Bulletin 29, 1925.
[3]Report of Water Commission, 1922.
[4]Abstract of thesis for Doctor of Philosophy in Economics, University of Illinois, 1933.

INTERNATIONAL FILTER CO.

Water Purification, Hydraulic Control and Chemical Feed Equipment

59 E. Van Buren St., CHICAGO, ILL.

Gravity Filter and Zeolite Softening Plant

INFILCO SERVICES

International Filter Co. specializes in the design and manufacture of water purification equipment; hydraulic measurement and flow control apparatus; chemical feeders and proportioning devices to meet municipal, institutional and industrial requirements. A complete laboratory and staff of engineers are maintained to make unbiased reports and recommendations. This service is intended to cooperate and not conflict with the work of any representative or engineer of the prospective purchaser.

FILTRATION PLANT EQUIPMENT

Infilco equipment is available in types and sizes to meet every requirement of a modern filter plant. **Infilco**-equipped plants centralize equipment responsibility and assure coordinated results. For the new plant—as well as rebuilding of old plants—**Infilco** offers:

Aerators of all types. **Automatic Control Equipment. Chemical Feeders**—Dry and Solution Types. **Lime Feeders and Slakers. Chemical Proportioners. Coagulators, Clarifiers** and **Settlers. Filter Operating** and **Control Tables. Filter Underdrain Systems. Flow Controllers, Indicators, Recorders** and **Proportioners. Gauges. Hydraulic Valve Controls. Iron and Manganese Removal Plants. Mixing Basin Equipment. Pipe Gallery Specialties. Recarbonating Plants. Sampling** and **Observation Tables. Taste and Odor Removal Plants. Venturi Tubes** and **Infilco Meters. Water Level Controllers,** Etc. Whatever the requirement, you will find that **Infilco Water Purification Equipment** has maintained its leadership in design and quality—and has kept in step with modern improvements.

INFILCO PRESSURE FILTERS are available in either vertical or horizontal steel shell types and may be used singly or in a battery of two or more units to obtain the desired capacity. Sizes range from small units of as little as 40 G.P.H. to the horizontal units having capacities of thousands of gallons per hour. **INFILCO GRAVITY FILTERS** are manufactured in wood tank or steel tank types, in sizes from 4 feet in diameter.

INFILCO WATER SOFTENERS

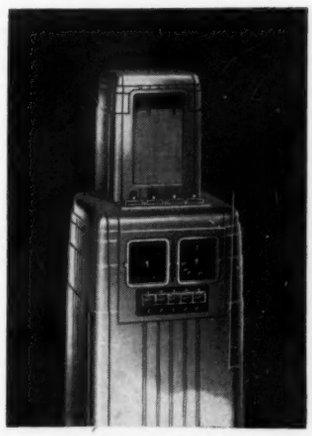
INFILCO ZEOLITE SOFTENERS are built in both pressure and open types, in sizes to meet any capacity requirement. These softeners may be furnished with either of several types of high capacity manufactured zeolites or greensand zeolites, to assure economical and efficient softening of various types of waters. Controls are furnished for either manual, semi-automatic or full-automatic operation, as desired.

INFILCO LIME-SODA SOFTENERS are made to meet any operating demand—or equipment is available to modernize old softening plants. Uniformity of treatment guaranteed. Capacities from 75 gallons per hour to millions of gallons per day. These softeners may be arranged for any desired degree of automatic operation, pre-coagulation, post-recarbonation, etc., and utilizing wood, steel or concrete sedimentation tanks or basins.

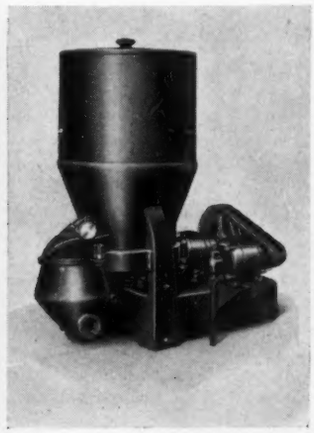
AUTOMATIC OPERATION

Although **Infilco Filters** and **Zeolite Softeners** may be furnished with no more than necessary essentials, these filters and softeners are equipped, if desired, for full-automatic operation, or any degree of refinement between these two extremes. **Infilco ROBOTROL Automatic Filter** and **Softener Operators, Hydraulic Valve Controls, Single Control Valves, Loss of Head** and **Capacity Alarms** and **Actuators,** etc., are available to provide semi-automatic or automatic operation and may be installed to modernize, habilitate and increase the efficiency of existing water filter and water softening plants.

Infilco ROBOTROLS provide centralized and simplified automatic control and accurate timing for each operation in the complete series of filter or softener operating functions. The **ROBOTROL** is a development in step with the modern trend which recognizes that a frequently performed series of mechanical operations is accomplished most efficiently when each operation is initiated automatically and timed precisely.



Robotrol Operator



Type D Dry Chemical Feeder

The results show:

1. That soap bills increase as the hardness of the water with which soap is used increases.
2. That even with a relatively soft water, a considerable quantity of soap is required to remove dirt and grease.
3. That by taking Superior as a basis for comparison, the annual per capita soap waste is: Bloomington, 2.9 lbs.; Champaign-Urbana, 10.7 lbs.; Chicago Heights, 16.6 lbs.
4. That this loss in Chicago Heights would amount to $15.00 per year per family of four.

From the results of this study an equation was formulated to show the degree of hardness necessary in any particular water supply in order that the economy in soap obtainable by the use of soft water would pay for the cost of softening.

$$X = \frac{C - 75D + 75F}{F - D}$$

X = hardness of water supply in p.p.m., the softening of which will be paid for in soap economy alone.
75 = demonstrated attainable hardness of water in p.p.m., from municipal water softening plants.
F = soap waste per capita per year per p.p.m. hardness.
C = capital overhead charges, including superintendence, per capita per year.
D = cost of chemicals per capita per year per p.p.m. hardness.

Mr. Hudson states that if this equation is applied to data for Champaign-Urbana and the hardness of the raw water tested only 145 p.p.m. (it is actually 298 p.p.m.) a municipal water softener that would soften the water to 75 p.p.m. would save enough in soap for home use alone to pay for itself.

Effect of Hard Water on Power and Heating Systems

Heating hard water causes it to deposit scale in water pipes, heating coils, boiler tubes, and boiler shells. The heat loss due to scale, 1/50 to 1/9 inch thick, has been computed to be from 7 to 16 per cent.[5] This means that with scale 1/9 inch thick, 16 cents of every dollar paid for coal is lost. This is in addition to the trouble, cost of drainage, and time lost in getting rid of the scale. According to an estimate of the American Railway Engineering Association,[6] the damage caused by one pound of scale is 13 cents. The Association further estimates that the improvement in operating and maintaining locomotives, due to water softening, amounts to a saving of from $4,000 to $9,000 per locomotive per year.

Hard Water Stultifies Growth of Cities

A study of ten Illinois cities shows[7] that eight have comparatively soft water supplies as judged by midwestern standards, whereas the other two have supplies that are excessively hard. The two hard water cities will be designated as A and B. Both are situated in rich agricutural sections and are advantageously located with respect to large markets. In spite of these advantages they have shown a very slow rate of growth. In 1880, A and B together had 26 per cent of the total population of the ten cities. In 1920 they together had only 13.7 per cent.

Manufacturing industries which require soft water for their successful operation, in establishing plants select communities having satisfactory water, other things being equal.

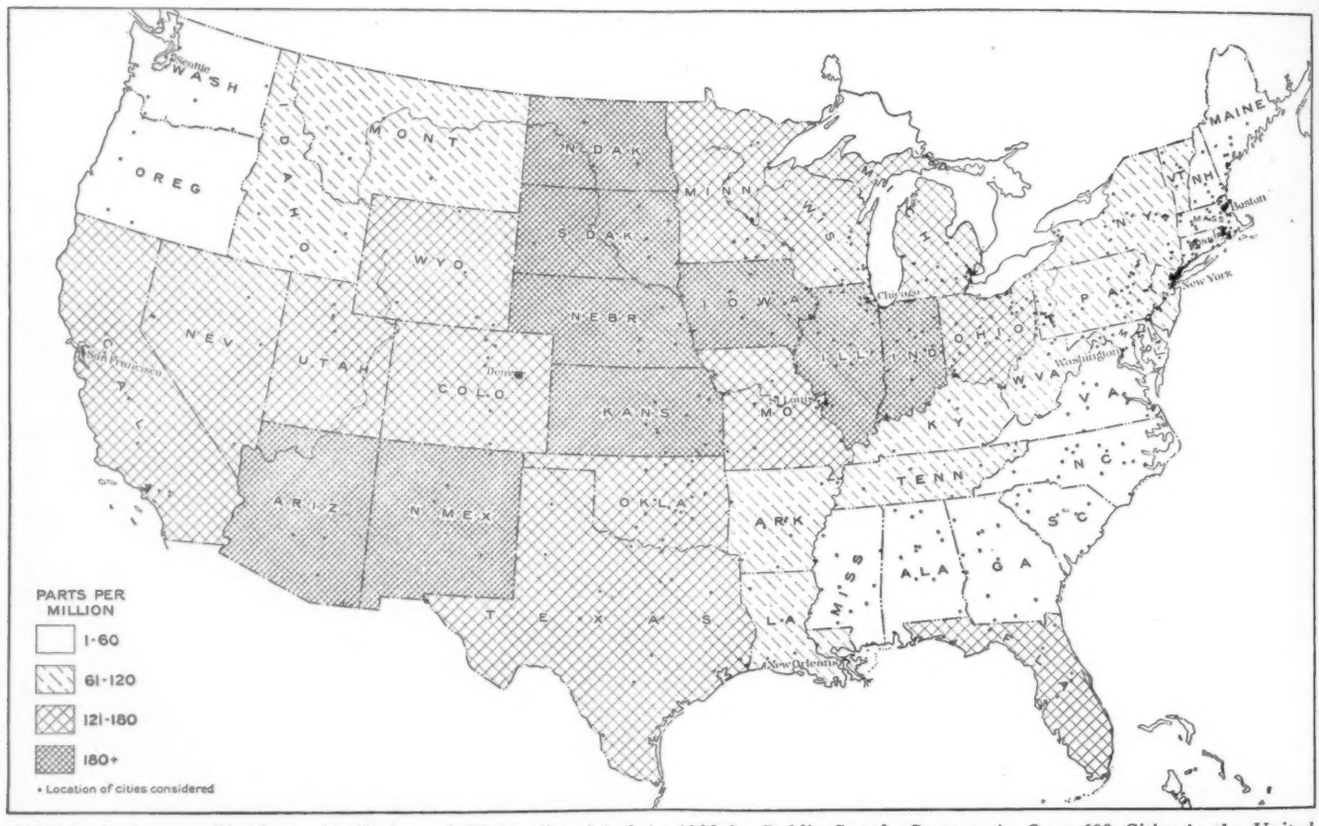
[7]Alvord, Burdick & Howson (Chicago), a private communication.

Cost of Softened Water vs. Other Commodities

"Cheap as dirt" is a common expression, but even expensively treated water is *much* cheaper! Two hundred and forty-one gallons of water equal one ton. Five cents a ton would be a little over 20 cents per 1,000 gallons, which is more than the average consumer pays for water in the larger and medium sized cities. A ton of dirt delivered would cost many times this amount.

The cost per capita per year for various domestic services by a family of five in Columbus, Ohio, is shown in the chart on the preceding page.

[5]U. S. Bureau of Mines, Tech. Paper 218.
[6]Bulletin, American Railway Engineering Association, November, 1923.



Weighted Average Hardness, by States, of Water Furnished in 1932 by Public Supply Systems in Over 600 Cities in the United States (Reprinted from U. S. Geol. Survey Water Supply Paper—658)

FILTRATION EQUIPMENT CORPORATION

Sales Office: 10 East 40th Street, New York, N. Y.

PRODUCTS: THE AUTOMATIC MAGNETITE FILTER — CONKEY ROTARY VACUUM FILTER

THE AUTOMATIC MAGNETITE FILTER:

The magnetite filter is an automatic mechanical cleaner strainer for effective removal of suspended solids from primary and secondary settled sewage effluents at reasonable cost.

Magnetite Filters in Operation, Elmira, N. Y.

The filter medium consists of a three-inch depth of magnetite iron ore screened to size and supported on a non-corrosive screen. A solenoid alternately magnetized and demagnetized washes the fine solids caught between the particles of ore by lifting and dropping a narrow strip of the filter layer. Wash water containing the impurities passes over into a separate compartment and is pumped back for re-treatment or other disposal.

DESIGN FEATURES:

Magnetite filters are now being designed for: (a) Upward or downward flow as an integral part of circular or rectangular primary or secondary settling tanks; (b) for installation in separate structures following primary or secondary sedimentation. The separate structures may be either circular or rectangular in shape. Fine or coarse grained magnetite may be used, depending on local requirements.

INSTALLATIONS:

The present automatic magnetite filter is the result of eight years' development and full scale operation. Magnetite filter installations are now in operation to treat a total maximum effluent flow of over 400 m.g.d.

APPLICATION:

In Plain Sedimentation:—Magnetite filters reduce settling capacity and improve the effluent by 40%. Settling for 1.5 hours plus magnetite filtering removes 70 to 75% of the suspended solids from raw sewage. Chlorine demand is 15 to 25% less for filtered than for unfiltered effluents.

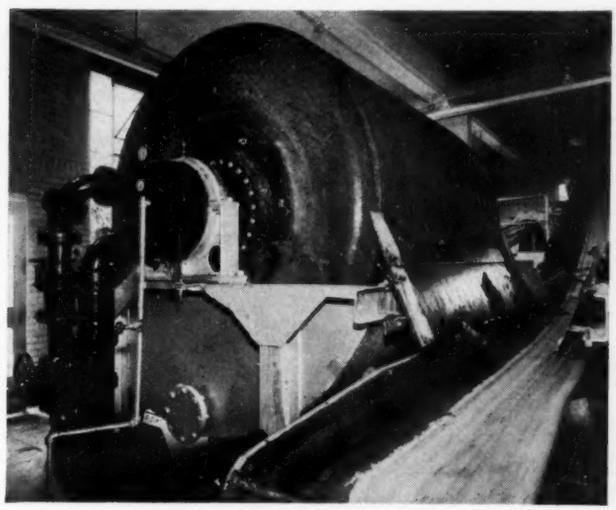
Chemical Treatment:—Magnetite filters reduce coagulation and settling time, save 50% of the chemicals required and improve the quality of effluent.

Activated Sludge:—Magnetite Filters reduce size of settling tanks, improve the effluent or save aeration tanks and power for compressing air. They act as a safeguard against irregularities in operation and as a polish on the final effluent.

Trickling Filters.—By installing a magnetite filter on preliminary settling tanks, it reduces their size and also reduces the physical suspended solids load applied to the trickling filters. On final humus tanks it reduces their size, strains out solids which fail to settle and polishes the final effluent.

Filtering through Automatic Magnetite Filters results in uniform effluents irrespective of variation in character of influent and helps to eliminate problem of secondary sludge depositions in receiving bodies of water.

Putrescible solids are removed from the sewage effluents by the magnetite filter at lower costs per ton removal than by any other method in the same range of treatment.



Vacuum Filter at Elmira, N. Y.

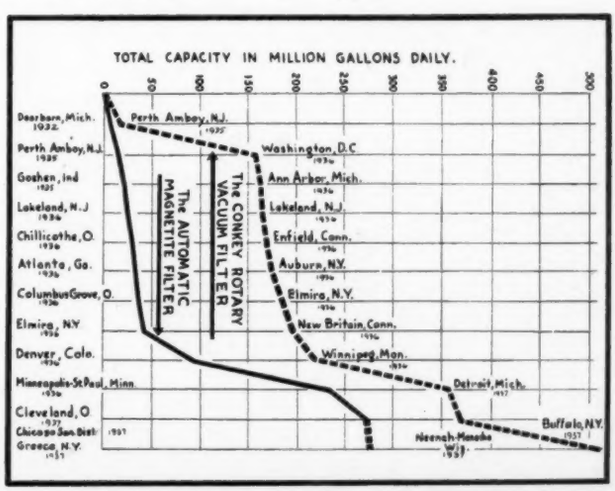
CONKEY ROTARY VACUUM FILTERS:

For dewatering of raw settled, chemically coagulated and activated sludges.

Built of the most improved design and best of materials for acid or alkaline conditions.

Produces cake of 8 lb. dry solids per sq. ft. per hour with 1.5% ferric chloride and 8% lime and a resultant moisture content of 65%.

Conkey vacuum filters now in operation or under construction at sewage plants treating a total maximum sewage flow of 800 m.g.d.



Progress of Magnetic and Vacuum Filter Installations

CONTROL OF ALGAE*

By FRANK E. HALE, Ph.D.

Dept. of Water Supply, New York City

Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into arms by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by the barrel arrangement shown. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sets on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F.	Pounds of Copper Sulphate Crystals ($CuSO_4.5H_2O$) Per 100 lbs. solution.	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.2	371.1
50	122	39.1	433.7
60	140	44.5	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.*, in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys may *genera*, in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect— Org. destroyed	Taste destroyed
Synura 1—25	0.3	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Uroglena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500.	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. Cyclotella has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia*, have been controlled on occasions. *Daphnia*, red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

*This material has been taken from the very useful booklet—"The Use of Copper Sulphate in Control of Microscopic Organisms"—(1935 revision) published for free distribution by Nichols Copper Co., New York City.

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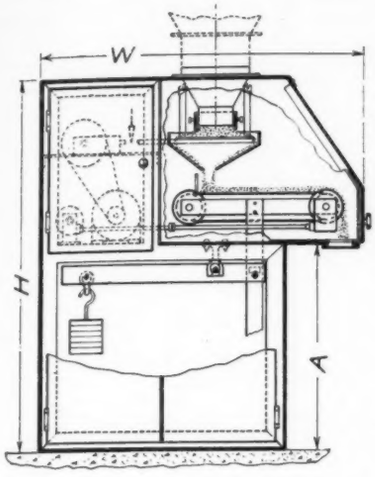
GRAVIMETRIC FEEDER—BELT TYPE



The particular advantage of this type of feeder lies in its large feeding capacity and small space required. Note that it can be installed under a bin, the outlet of which is only 5 ft. above the floor on which the feeder is located, and in a floor space 48″ x 36″. Accuracy within 2%. Mechanical recorder, not shown, may be furnished. Feeding capacity may be as low as 10 lbs. per hour or as high as 5,000 lbs. per hour.

Gravimetric Feeders offer many advantages not obtainable with volumetric feeders. These feeders deliver material accurately at a pre-determined rate, regardless of density, and operate an alarm if there is any interruption in the rate of feed.

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The well-known Omega Jet Type Lime Slakers have proved their dependability and efficiency in approximately a hundred installations. Omega Slakers are insulated and equipped with thermostatic water control. Efficient dust and vapor removal equipment allows operating temperatures up to 200° F. without outside vents. The impeller type agitator cannot become clogged by thick mixtures and the slaker design eliminates submerged bearings with their stuffing boxes and packing glands. High temperature slaking is accomplished easily.

DISK FEEDERS

Model No. 1 Disk Feeders are recommended for average feeds up to 30 lbs. per hour of carbon, lime, soda ash, bleaching clay, sodium aluminate, etc. Model No. 1-A Disk Feeders are designed especially for feeding free-flowing materials, such as alum or ferrous sulphate, at average rates up to 30 lbs. per hour. Disk Feeders are not recommended for extremely large feeds or for use with extension hoppers.

UNIVERSAL FEEDERS

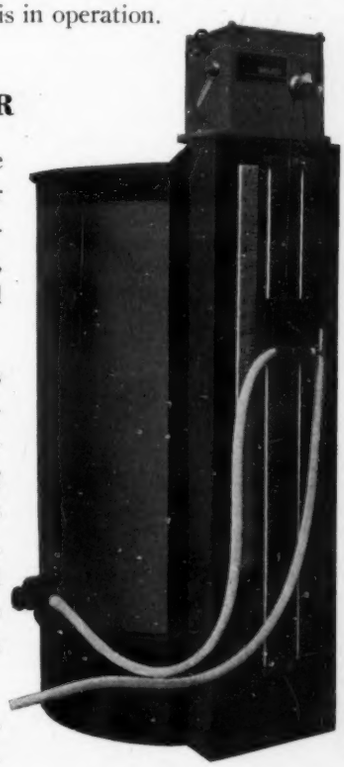
Omega Universal Feeders are built in three standard sizes, providing capacities suitable for handling from a few pounds to several carloads per day. Universal Feeders will handle any dry material—from lumps to fine powder—including such materials as crushed quicklime, hydrated lime, soda ash, sodium aluminate, alum, etc. Special mixing chambers can be furnished for dissolving Ferrisul.

Universal Feeders can be mounted on scales, and are especially designed for use with extension hoppers or filling chutes.

LABORATORY STIRRERS

Omega Laboratory Stirrers, for making coagulation and flocculation tests, eliminate guesswork in plant operation. The stirrers are made in 3, 4, 5 and 6 unit sizes. Paddle speeds are positive, regardless of the number of samples being stirred. Samples may be removed or replaced while the machine is in operation.

PRECISION FEEDER



This is a very accurate decanting type of feeder for liquids, such as Hypochlorite, Ferric Chloride, Ammonium Sulphate, and similar solutions.

The illustration shows a standard Omega Precision Feeder with a 24-gallon tank and feeding range from 1 to 10 pints per hour. A larger size, with 48-gallon tank and feeding range from 1 to 10 quarts per hour, is available.

Special Precision Feeders are built with capacities up to 100 gallons per hour or more. Tanks are steel, asphaltum or rubber-lined, depending upon the material to be fed.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA

Organisms—Odor:	Copper Sulphate[1] Parts per million	Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Aromatic, geranium, fishy			
Cyclotella†‡			1.0
Faintly aromatic			
Diatoma†			
Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	2.0
Meridion			
Aromatic			
Navicula†	0.07	0.6	
Nitzchia§	0.50	4.2	
Synedra†‡	0.36*-0.50*	3.0-4.2	1.0
Earthy			
Stephanodiscus	0.33	2.8	
Tabellaria‡	0.12*-0.50*	1.0-4.2	0.5*-1.0
Aromatic, geranium, fishy			
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Cœlastrum†	0.05-0.33	0.4-2.8	
Conferva†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium‡			0.5*-1.0
Grassy, nasturtium, fishy			
Draparnaldia	0.33	2.8	
Eudorina	10.00	83.0	
Faintly fishy			
Entomophora	0.50	4.2	
Glœocystis			
Offensive			
Hydrodictyon†	0.10	0.08	
Very offensive			
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina	10.00	83.0	
Faintly fishy			
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡	0.25	2.1	0.3*-1.0
Fishy			
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡	0.12*	1.0	0.5*-1.0
Moldy, grassy, vile			
Aphanizomenon‡	0.12-0.50*	1.0-4.2	0.5*-1.0*
Moldy, grassy, vile			
Clathrocystis	0.12*-0.25*	1.0-2.1	0.5*-1.0
Sweet grassy, vile			
Cœlosphærium‡	0.20*-0.33	1.7-2.8	0.5*-1.0
Sweet grassy			
Cylindrospermum	0.12	1.0	
Grassy			
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia			
Moldy, grassy			
Protozoa:			
Bursaria			
Irish moss, salt marsh, fishy			
Ceratium†‡	0.33	2.8	0.3*-1.0
Fishy, vile, (rusty brown color)			
Chlamydomonas	0.50-1.0	4.2-8.3	
Cryptomonas	0.50	4.2	
Candied violets			
Dinobryon‡	0.18*	1.5	0.3*-1.0
Aromatic, violets, fishy			
Endamœba histolytica (cysts)			25.0-100.0
Euglena	0.50	4.2	
Glenodinium	0.50*	4.2	
Fishy			
Mallomonas	0.50	4.2	
Aromatic, violets, fishy			
Peridinium	0.50*-2.00	4.2-16.6	
Fishy, like clam-shells			
Synura‡	0.12*-0.25	1.0-2.1	0.3*-1.0
Cucumber, muskmelon, fishy, bitter taste			
Uroglena‡	0.05*-0.20*	0.4-1.6	0.3*-1.0
Fishy, oily, cod-liver oil taste			
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa†	5.00	41.5	
Very offensive decayed			
Cladothrix	0.20	1.7	
Crenothrix†‡	0.33 -0.5*	2.8-4.2	0.5*
Very offensive decayed, medicinal with chlorine			
Leptothrix†			
Sphaerotilis, natans†	0.40	3.3	
Very offensive decayed			
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 -0.50	0.8-4.2	
Nitella flexilis†	0.10 -0.18*	0.8-1.5	
Objectionable			
Potamogeton†	0.30 -0.80	2.5-6.7	
Nais†			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

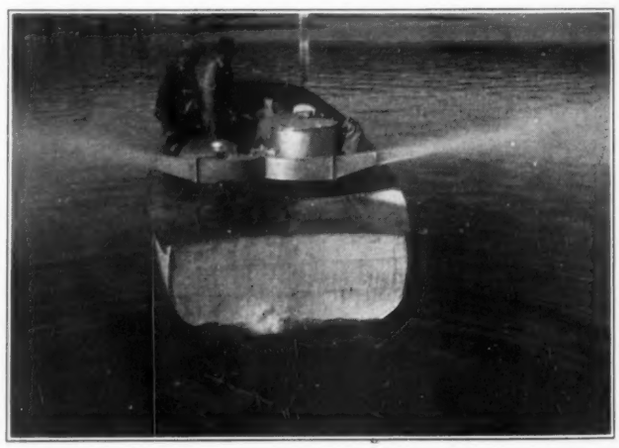
[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).



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PRODUCTS—"Aqua Nuchar," Activated Carbon

REFLECTIONS IN RETROSPECT

IT SEEMS but a very short while ago since George R. Spalding demonstrated at Hackensack, New Jersey, the effectiveness of powdered activated carbon in the treatment of water for taste and odor removal. Previously, attempts had been made to introduce the product in granular form but indications of high equipment cost and uncertainty of results had made water operators somewhat skeptical of this new medium as a dependable and economical purification tool.

Literally, much water has gone over many dams since that time—six or seven years ago, and the doubts and fears then felt have been entirely dissipated. So great has been the progress in the adoption and use of powdered activated carbon as a positive means to control tastes and odors in drinking water, that in the neighborhood of 1,000 plants—municipally and privately owned—in this Country alone have proven its benefits in this respect and its use is fast spreading throughout the world; a testimonial to the initiative and enterprise of those responsible for the operating of American water plants.

Today, there is such faith and confidence in activated carbon as a means of eliminating tastes and odors, that its use can be safely looked upon as a standard purification practice and no other method of water purification has achieved such a position in so short a time; surely concrete evidence of the merit of the product for such purpose.

In retrospect, one can go back to the questions of doubt that were raised; such as, powdered carbon would not be removed in the sand filters; it might decrease the filter runs, also accelerating mud ball formation. It was further questioned whether powdered carbon would remove tastes and odors of a serious nature, or, if it did, the treatment would be too costly. Wide experience in operating hundreds of water plants had proven to the contrary, and it has been demonstrated conclusively that there is no taste and odor condition which cannot be corrected when an adequate quantity of Aqua Nuchar is used.

Trouble with the control of taste and odor is one of the biggest worries of the water plant officials because such a condition reaches and registers in every home in the community. Naturally, the cost of furnishing a uniformly palatable water at all times must be considered. In the case of unusual taste and odor epidemics, quantities up to 300 lbs. of Aqua Nuchar per million gallons have been used but such conditions rarely occur, and during a period of twelve months the cost per million gallons is negligible. Taking the average case, an official study of over one hundred water plants shows the average quantity reported was approximately 16 lbs. per million gallons; and even if this average was doubled, obviously it would be a very small amount to pay for water that satisfies.

As the use of powdered activated carbon became wider, some further benefits from the treatment developed. For example, the application of the carbon along with the alum in the mixing chamber has resulted in a better floc formation and, in some cases, to such an extent that the amount of coagulant has been reduced. Further, it has been convincingly proven that the sludge in the sedimentation basin is stabilized by inhibiting decomposition, preventing gas formation and the incidental scum. In certain plants where the supply of raw water is badly contaminated, necessitating super-chlorination, it has enabled the operators to get rid of the objectionable chlorine taste by reason of the carbon acting as a dechlorinator, so that these operators can not only supply an absolutely safe water but also a palatable one, thus getting rid of a lot of complaints.

Today, activated carbon is the cheapest form of insurance that a water plant can take out to protect the palatability of its supply under all and any conditions. Necessarily, such conditions vary considerably throughout the Country and where epidemics occur—as they sometimes do—the cost of the carbon may seem high during this temporary situation. It is calculated on the basis of 20 lbs. of carbon per million gallons of water used each day in the year based on a per capita consumption of 100 gallons daily, it would make the cost to each individual within the community only slightly over 3c per year. To those plants that are subject at certain seasons to severe epidemic conditions, we recommend the use of a small quantity of Aqua Nuchar every day, depending upon individual circumstances, as being more economical because when the carbon is well distributed throughout the plant as the severe tastes and odors arise, the condition will not reach a point where excessive dosages are needed. Such a procedure will provide maximum insurance of palatable water without increasing the total premium paid.

J. Wranek

SALES MANAGER

TASTE AND ODOR CONTROL PRACTICES

By F. E. STUART

Activated Alum Corporation

Taste and odor control is now second only to the production of a safe water. The cost has been studied carefully and has been weighed against its importance as a routine treatment.

Now that the economics of taste and odor control by applying large dosages of powdered activated carbon have been compared with the economics of closely controlled coagulation, involving carbon adsorption, a new flow scheme is becoming apparent. A combination of these two methods of treatment appears to be the most overall efficient and economical.

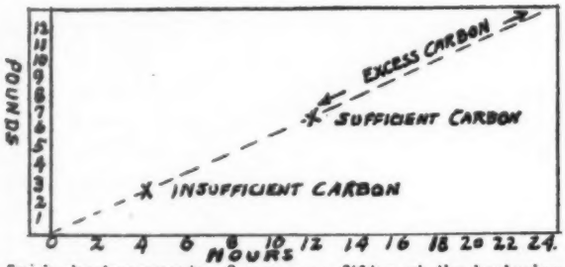
A short review is necessary to bring up to date the work that has been done on carbon by observers in the field. Further, to point out why this new type taste and odor control flow scheme is the most practical.

When alum is added to water and coagulation is produced, a large percentage of taste producing elements in the raw-water is precipitated in the settling basins. This is common practice and the effectiveneness coagulation is taken for granted.

Previous to the introduction of activated carbon, these precipitated impurities underwent decay and generated gases and liquids of decomposition, which contaminated the newly coagulated water passing through the basins. Putrefying and liquefying sludge in the settling basins is a more common cause of tastes and odors than generally realized. A high chlorine demand in the filtered water and of tastes in dead ends are created by the same phenomena. This is not difficult to appreciate when one remembers how badly the basins smelled when they were last cleaned.

Carbon in the Coagulation Stage

At Daytona Beach, Fla., Superintendent Tippins in 1931 found that carbon used in the coagulation process would inhibit bacterial activity in the settled sludge—resulting in odorless sludge and odorless filtered water. These findings were later confirmed by Furman at Toledo, Ohio, and Fitzgerald at Norfolk,



* Graph showing amounts of carbon on filter at the beginning and end of a filter run - when adding carbon continuously to the applied water - based on 12 pounds per million gallons and 24 hour filter run.

Va. This effect of carbon on coagulated sludge has become known as "Stabilization of Sludge."

Because of the good results obtained, other observers added carbon to the mixing chamber in dosages sufficient to remove the tastes and odors present,—dosages between 18 and 32 pounds per million being the most common.

Middlestadt in Sacramento, Cal., about this same time made a careful study of the amount of carbon needed to stabilize sludge and found this dosage to be very small—from 2 to 4 pounds per million gallons. In a recent survey 54 per cent of the plants now using carbon for taste and odor control have been adding small dosages of carbon to the mixing chamber to stabilize sludge and condition the filter sand.

Split Dosage

Later work showed a further reduction in the cost of carbon treatment by utilizing a split treatment; adding half of the total carbon dosage to the mixing chamber and half to the water flowing to the filters. More complete taste control has been accomplished thereby.

Comparing the results between large dosages of carbon added continuously to the water flowing to the filters, large dosages added to the mixing chamber and split treatment the last proved to be the most economical. This brought about the latest change in treatment practice—adding the total amount of carbon to each filter after washing (about 4 to 6 pounds per million gallon filter area) and the addition of sufficient carbon to stabilize sludge and condition the filter sand, along with the alum dosage. A convenient method of doing the latter is to utilize the ready prepared activated alum which contains the required quantity of powdered carbon.

The floc produced by activated alum is more easily controlled than ordinary alum, because of the millions of tiny activated carbon particles which assist in the formation of the floc. A stable sludge will result and stable filter sand also, because the carbon particles are distributed throughout the floc. The floc does not break down as easily as ordinary alum floc and it has been found that less residual alumina is present in filtered water when activated alum is used.

Filter Dosing

Individual observers, led by Smith at Richmond, Va., showed reason why carbon should be added in one "Shot" dosage to the filter *after* washing instead of adding carbon continuously to the water flowing to the filter.

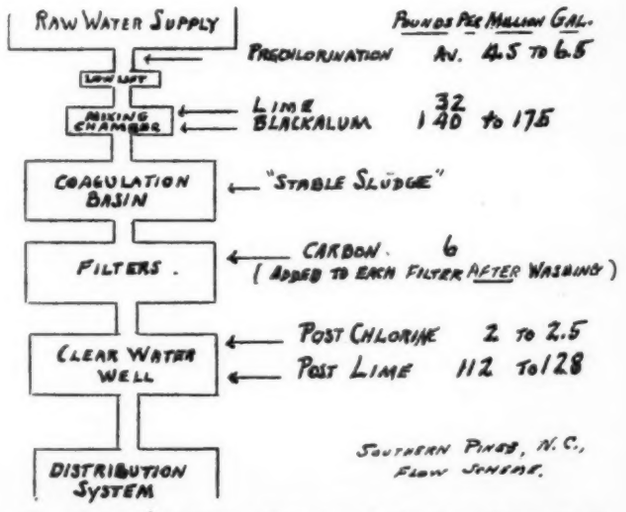
The common basic reasoning for such applications is that with carbon added continuously to the water flowing to the filters (we will say 12 pounds per million gallons), there is more carbon on the filter when it is taken out of service for washing than at any other time. Likewise, there is insufficient carbon on the filter for the first few hours of service, unless higher dosages than actually needed are applied. By estimating the amount of carbon actually needed for each run the dosage if added all at one time, produces a big saving in carbon. Average dosage of 4 to 6 pounds, per million gallons of filter area, seems to meet requirements between filter washings.

The following typical new type flow scheme for taste and odor control is used by Mills of the Southern Pines, N. C., Water Department:

Treatment	Pounds per Million Gals.		
Prechlorination	4.5	—	6.5
Lime, average	32		
Black-Alum (Activated Alum), average	140	—	175
Activated Carbon	6*		
Post Chlorine, average	2	—	2.5
Post Lime, average	112	—	128

This review points out why taste and odor control can be obtained more economically by means of good coagulation and car-

*Added to each filter following the wash.



Flow Scheme of Water Department, Southern Pines, N. C.

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"Reduces Chlorine Demand"
"Eliminates Chlorine Tastes" by dechlorinating high pre-chlorination residuals
"Reduces 20 degree Bacteria Count" by inhibiting bacterial activity in sludge and filter sand
"Eliminates Dead End Tastes" by adsorbing end products of decomposition in pretreatment
"Removes Tastes and Odors" by the millions of powdered activated carbon particles present during coagulation and filtration—When additional carbon is required for severe tastes it is added directly to each filter after washing

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Write for samples and technical information.

bon added to each filter immediately after washing—than high dosages of carbon at any one point in the treatment.

Carbon is now regarded as a routine treatment—to improve coagulation and remove tastes.

Carbon in the pretreatment through activated alum and the addition of 4 to 6 pounds of carbon per million gallon of filter capacity (added all at one time to the filter after washing) is now considered the most efficient and economical method. (See flow scheme).

For serious taste and odor epidemics which are only temporary, large dosages of carbon are necessary and should be applied as a split treatment.

Ammoniation

Suggested by Enslow and probably first introduced by Jordan at Indianapolis, Indiana, later adapted in many plants including Easton, Pa.; Trenton, N. J., and Fort Pierce, Fla., etc., the trend in ammonia application during the past year has been in connection with its use after filtration; it being added after the post-chlorine dosage.

This seems to be the most economical method of application because the dosage of ammonia used is that to combine with only the existing free chlorine.

Users of ammonia continue to favor anhydrous ammonia in cylinders because of ease of application and accuracy of control.

It is well known that ammonia, unless used in the proper concentration in the pretreatment, will in many instances increase algae growths along the sides of the settling basins. This increase in algae growth is controlled, however, if high dosages of ammonia and chlorine are used. These high dosages are uneconomical, and, therefore, prechlorination alone is generally adopted as the most economical practice; adding the ammonia after filtration.

Chlorination

The benefits of such a versatile product as chlorine cannot be outlined in more than a general way. Chlorine in the pretreatment is becoming more generally used, because prechlorination has several advantages in routine plant operation. All plants should have duplicate chlorinators for post-treatment and provisions for prechlorination.

Experiences of the writer have been that high residuals in prechlorination are not advisable at any time. High prechlorination residuals hinder taste and odor control.

High prechlorination residuals are not necessary to improve coagulation or lengthen filter runs. Experiences of Fitzgerald at Norfolk, Va., show that the typical "water flea" can be stunned with prechlorination, without a residual reaching the filters. Prechlorination at the rate of 8 pounds per million gallons was just as effective as 30 pounds. The chlorination did not "kill," but "stunned" them to such an extent that the alum floc would precipitate them and then the filter runs lengthened out.

Many other experiences with chlorine in the pretreatment confirm the writer's opinion that it is a most useful tool to improve general plant operation, but should not be used in concentrations to produce high residuals in applied water. Especially is this true when dealing with algae tastes.

Acknowledgment: This article has been drawn largely from a paper read by the author before the Kentucky-Tennessee Section of A.W.W.A., March, 1936.

Inclined Diagonal Pipe Runs—Calculating Pipe Lengths

By CHARLES FRICK

Darby, Pa.

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (Θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$D = \sqrt{A^2 + B^2 + C^2}$ Formula I

$L\ (\Theta)^{-\tan} = \dfrac{\sqrt{A^2 + B^2}}{C}$ Formula II

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (Θ) and length of pipe required on 8″ line.

$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$
$= \sqrt{30.25 + 9 + 217.56} = 16.025'$ say 16′0″

$L\ (\Theta)^{-\tan} = \dfrac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \dfrac{\sqrt{30.25 + 9}}{14.75}$

$= \dfrac{\sqrt{39.25}}{14.75} = \dfrac{6.265}{14.75} = 0.42474$

$L\ (\Theta) = 23° +$ and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle of fitting (Θ) decided upon, then

$D = \sqrt{A^2 + B^2} \times \text{Csc}\ (\Theta)$ Formula III

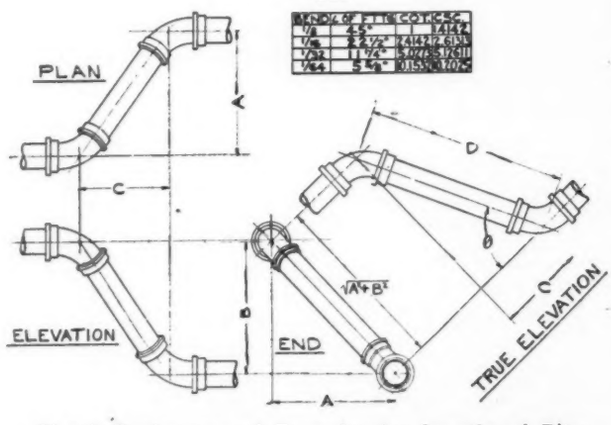
$C = \sqrt{A^2 + B^2} \times \text{Cot}\ (\Theta)$ Formula IV

Example: Let A = 8′0″, B = 9′6″, (Θ) = 45°
Find—C and length of pipe required on 12″ line.

$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc}\ 45°$
$= \sqrt{64 + 90.25} \times 1.4142$
$= 17.56' = 17'6\frac{3}{4}''$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4⅞″

$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot}\ 45°$
$= \sqrt{64 = 90.25} \times 1$
$= 12.42 \times 1 = 12.42' = 12'5''$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

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METERING: PRACTICAL METHODS OF PROCEDURE*

By E. H. RUEHL†

"To meter or not to meter?" That is the question.

Those who have gone through the problem of making initial installation of water meters know what significance these few words can have and what discussions can be caused thereby.

However, metered water service is being acknowledged more and more as being the best all-round method of distributing the indispensable commodity, water. This is especially true since the unprecedented drought of 1930, and I am sure that if more communities were metered at that time the effects of the drought would have been less severe due to the lessened wastage of water.

Why Services Should Be Metered

There are many good reasons why water services should be metered, a few of which are:

1. It is the fairest way of selling water, as all customers pay in proportion to their respective consumptions.

2. The water department or company has a pretty good check on the amount of water sold and by comparison with readings of a master meter can better establish losses and leakage and thereby reduce waste in the system in general.

3. Leaks in consumers' service lines can better be located.

4. Knowledge of the various water consumptions is essential in establishing equitable water rates, and the only way in which this information can be obtained and analyzed is by metering of all services.

In some cases, especially in the municipally owned plants, there are certain institutions, such as schools, hospitals and the like, that are supplied with water without charge, and these should be metered and read regularly to get the full benefits of 100 per cent metering.

And here let me digress a little to state that the words municipally owned are generally a misnomer, as in the majority of cases the municipality has a large obligation in the form of outstanding bonds, and the only part that is really municipally owned is the amount covered by bonds purchased back, or some such similar item. This is mentioned here because in the municipally operated plants we are so often confronted with the statement that the people own the plant and for this reason they should have all the water wanted for some flat rate that is nowhere commensurate with the cost of producing the water, the fixed charges being lost sight of entirely.)

5. It has been proven that as meters are installed that consumers' wastes have been reduced and this in turn effects economies in the amount of power required to pump, if it be a pumping plant, and in treatment costs, which are getting higher and higher every day.

6. As the water requirements of the city are kept within bounds and more or less controlled, the size of the treating and pumping plants and storage and distribution systems are kept to a minimum, thereby keeping capital investment to a minimum, as well as the necessary interest and sinking fund charges, which all result in keeping of the water rates at the lowest possible figure.

7. As the time will most likely come when sewage treatment will become necessary in a good many places, the lowering of the water losses and wastes will redound to the town's advantage in requiring a plant of smaller capacity than would be necessary if water usage and wastage were uncontrolled. Likewise, sewage pumping costs will be less.

With all these reasons in favor of metering, the only ones against it are generally found to be caused by the selfish motives wherein certain customers may want to use unlimited quantities of water without paying a just price therefor. This can be overcome in a great many cases by explanation, and, in spite of the fact that many may be adamant at first, good results are usually obtained.

Another argument against metering is sometimes set forth in that it is claimed that sanitary conditions will not be maintained if water usage be curtailed due to the installation of meters, but it has been shown that for all purposes about 25 gallons per capita per day is all that is absolutely necessary. Under any ordinary rate the cost for this requirement for the average family for an entire month would be modest, in most cases less than the cost of one filling of the gasoline tank of the automobile.

It can therefore be seen that metering is beneficial to both the municipal plant or privately owned company as well as to the consumer, since it contributes a means of compiling equitable rates and keeping bills to a minimum.

Ownership and Location of Meters

Since the type of meter and location of meter setting is governed to some extent by geographical location and local conditions, the remarks that are to follow must of necessity be confined more or less to a particular section and will apply to Virginia.

The ownership and location of the water meter are two subjects on which divergence of opinion exists. In the writer's opinion, the meter should be owned by the water department or company (being charged to capital account) and all maintenance should be done by the owners and charged to operating costs. In Virginia the meter setting just inside the curb line offers so many advantages over other locations that these readily outweigh any disadvantage in the nature of a small additional installation cost, should this be the case. In a good many houses in this section of the country there are no basements in which to locate a meter.

Advantages of Outside Setting

The advantages of such outside setting, located in the sidewalk space, are in general as follows:

1. Meter reading is greatly facilitated due to the fact that the reader never needs to wait for a response from the householder on knocking, and should the party be absent it would necessitate making another trip to get the meter reading if the meter were located inside the house. The distance the meter readers have to walk is lessened when outside settings are used, and this in turn permits more meters to be read per day.

2. The meter is always accessible to water department employees for reading, inspecting, testing and repairing.

3. The danger of the meter readers and other water department employees from attacks from vicious dogs is eliminated.

4. The chance of unauthorized persons entering the house in the guise of water works employees is greatly eliminated.

5. Chance of the meter being covered by rubbish, coal, kindling wood. etc., is done away with when the outside setting is used.

6. More accurate readings can be procured when outside settings are used because of better lighting outside than generally exists in basements, under porches or other places where meters might be set.

7. The line of separation between the water department and property owners' liability is clearly defined and there is not much chance of unauthorized connections being made behind the meter.

8. In case of necessity of cutting off the water for non-payment of bills there can be no dispute as to entering the premises if the meter and control are located at the curb line.

9. The outside setting should be in a locked box and, as it is below the ground, is not so apt to be tampered with as would a setting in a more conspicuous place not protected by a box.

10. Less danger of damage to the meter by hot water exists if set at the curb.

11. Danger from freezing is practically eliminated in a well set meter, and in case of fire in the building supplied the meter is not in danger of being destroyed.

In view of all these reasons the writer is of the opinion that the entire meter setting, including the necessary cut-off valve, should be located in the sidewalk space behind the curb line, and that the water department's or company's maintenance and obligations should stop at the customers' side of the meter.

Type of Setting

The following remarks apply to the smaller size meter up to 1-inch, and when larger sizes than this are used the condition must be studied separately and settings made to suit.

It is realized that a properly set meter, although not always the cheapest, will receive more attention in general from the water works operatives and in turn pay higher returns to the department.

It is a good plan to set the meter in a yoke with at least a control valve at the inlet side, although some prefer valves at

*From WATER WORKS AND SEWERAGE.

†Field consultant, Virginia League of Municipalities.

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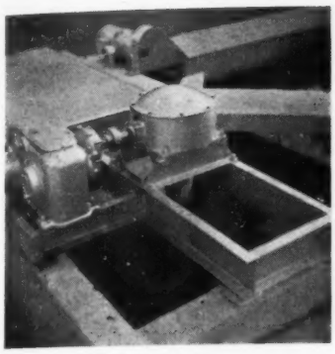
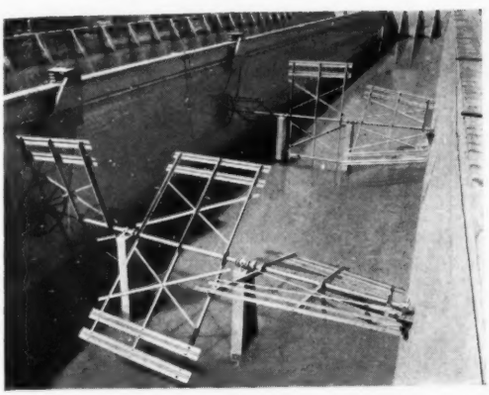


Dorrco Flash Mixer

The Dorr Company's function in modern waterworks practice is the pre-treatment of the turbid or hard raw water prior to final treatment. Three Dorr steps—mixing, flocculation and sedimentation—taken in sequence pay for themselves through reduced chemical consumption. The resulting treated water settles and filters more rapidly and yields a final filtered water of definitely improved qualities.

MIXING . . .

First comes mixing, in a Dorrco Flash Mixer. Coagulating or softening chemicals are introduced directly below the throat of a high speed impeller that rapidly and completely diffuses the chemicals throughout the incoming raw water.



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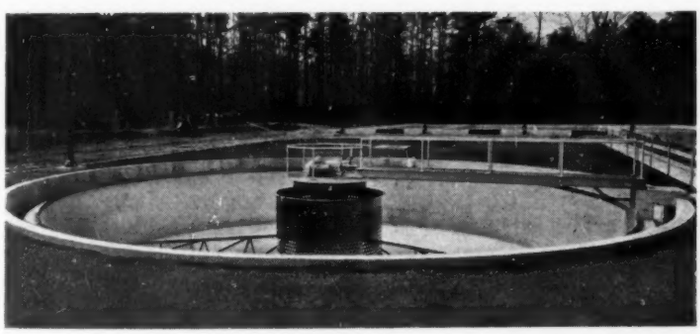
Next comes floc formation in a Dorrco Flocculator. Chemically-dosed water is given a series of gentle "barrel rolls," causing flocs to sweep through the water, impinge on and entrap light suspended particles and finally grow to large dense structures of improved settling and filtering qualities.

Chemical savings range between 20 and 30 per cent, generally repaying the installed cost in one to three years.



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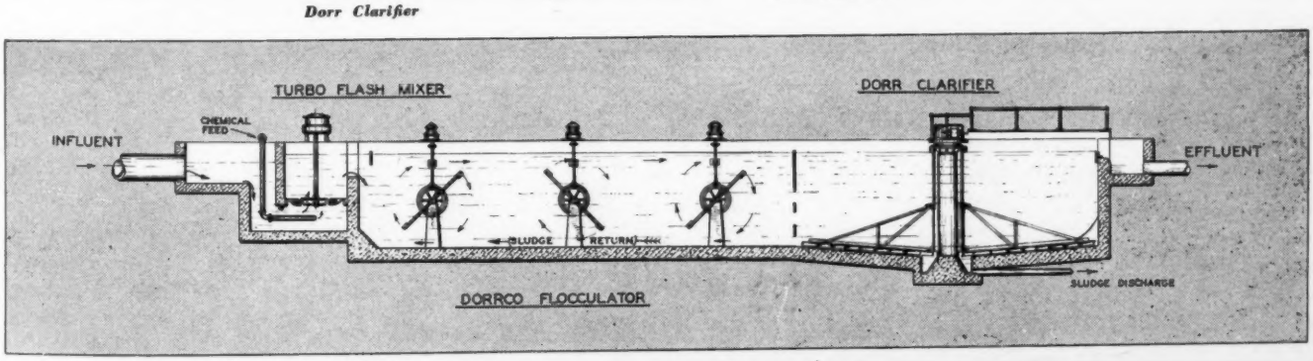
Finally, comes sedimentation in a Dorr Clarifier. Flocs settle continuously and are removed mechanically at maximum solid content. Clarified water overflows continuously across a peripheral weir and is ideally conditioned for filtration.

Write for our new bulletins "Flocculation & Mixing" and "Modern Municipal Sanitation."



both the inlet and outlet sides. This does away with the customary curb stop and box.

The meter in its yoke, and with the control valve, should be set in an earthenware, concrete or iron box with sufficient clearance between the risers, if they be used, that the cold ground outside cannot cause the water in the pipes or meter to freeze. A type of box that has proven very satisfactory in our section of the country is one 18 inches in diameter and 24 inches deep, with side slots at the lower end to accommodate the varying depths of the service pipe. The latter, we feel, should be about 24 inches below the ground.

It is important that a lid be provided that fits the top of the box tightly, preferably being locked on with some kind of a locking device. If the lid is fastened on there will be no circulation of air in the box and consequently less danger from freezing. Another advantage is that if the lid is kept on tightly there is less danger of persons tampering with the meter or of pedestrians catching their feet in the hole, with a possible damage suit resulting.

It is also very important that the bottom of the box extend below the maximum frost line so that the warm air from below can rise up around the meter and risers and keep the atmosphere in the box above freezing. In extreme cases it has been found that a smaller tile pipe about 8 inches in diameter put vertically into the ground below the bottom of the regular box (to reach warmer levels) overcame freezing troubles by admitting warmth from below.

Meter Reading

In the writer's opinion, meters should be read monthly, if this is possible, as by so doing a closer touch is kept on losses and wastes, and due to the visiting of each meter every thirty days the stopped meter and other irregularities can be more effectively dealt with. In case a customer has a leak he can be notified within a reasonable time if the meters are read monthly, but if they are read, say, quarterly, the amount of leakage passed will more likely be an appreciable amount and cause some disagreeableness when an attempt is made to collect the bill.

Experiences at Bluefield, Virginia*

If you will pardon personal experiences, it may be of some interest to tell how the town of Bluefield recently attacked the problem of setting 700 meters at the rate of something like 100 per week. This was carried on as follows:

A work sketch was first made up and the various kinds of equipment decided on. After the meters, yokes, boxes and covers were ordered out, some figures were made up giving the length of pipe to be cut from the service to allow for elbows, yoke, valve, etc., and the vertical distance that cover, meter, yoke and fittings required was figured and each made into a constant.

Actual installation started with several men digging holes, located from the curb boxes wherever possible, in a certain well defined section so that one foreman could keep all things going. Two men, both of whom had some previous pipe fitting experience, were formed into a "gang" and given instructions how to set the meters, and they then worked together for about a day. These men then were given a helper each and two setting "gangs" were formed and these two helpers were in turn given helpers and four setting "gangs" were formed in a few days. The work was carried through, with as many men as were necessary to prepare the holes ahead of them.

Tools Required

Each of these setting gangs of two men each was furnished with a ratchet die holder and one-half and three-quarter inch dies, a hack saw, two 10-inch Stillson wrenches, a pipe vise attached to a four-legged board, a home-made wooden straight-edge, and a pair of hip boots. The men provided their own rules. The meters, yokes, boxes, covers, pipe, etc., were supplied to the location by a Ford truck. Galvanized nipples of various lengths were purchased and used wherever possible, as they could be purchased cheaper than we could buy, cut and thread the pipe.

When the hole was opened down to the service pipe the meter-setting gang (two men) came along and the first thing they did was to lay the straight-edge across the hole and measure down to the service pipe, and from this the proper "constant," referred to above, was subtracted, which gave the length of risers necessary to bring the top of the meter to the desired point below the meter box lid. If there was a standard nipple of length somewhere near this dimension it was used. If not, the helper would cut pipe to the proper length and thread it. The meter setter in the meanwhile would be cutting a piece of pipe predetermined length out of the service line and threading the cut ends for elbows. The risers were then screwed in and the yoke and meter set, after which the box was put in the hole. By using a set of specially made hooks the box was easily adjusted around the meters and risers, and the cover put on.

Two men constituted the back filling gang and followed up all setting gangs, backfilling all holes and seeing that the lids were properly fastened.

If the existing cut-off in the service line was so that it could be used to control the water it was used, but if not the meter setter would cut and thread the pipe under pressure, which only took a very few minutes. He would screw the riser pipe with control valve on, bail out the hole, and go on without having to dig back to the main or cut the water off of a section of the town. The water lost amounted to very little.

One foreman looked after the entire job and 700 meters were set at the rate of about 100 per week.

The cost of this work complete, including tools, boots, and everything, was slightly under $19 per setting, which also included the changing of some services where it was necessary.

We believe that in a place where the services are fairly close together one foreman could handle about six meter setting gangs with the necessary hole diggers and could set about 150 meters per week, providing that everything is thoroughly planned ahead.

*When this article was written the author was City Manager of Bluefield, Va.—Ed.

Meter Repair Practices*

Water meter castings are painted by spray gun equipment. The meter casting sets on a turntable which revolves slowly. The colors used are Bronze and Aluminum.

Air chambers have been installed on the influent side of all the meter testing machines. This eliminates water hammer caused by the quick opening and shutting valves, especially effective when testing large size meters.

The use of Monel metal baskets for dipping meter parts in Dearborn 134 solution has been much more economical than the use of cheaper baskets.

An electric drill held in place by a suitable clamp arrangement is used for cleaning meter parts. The drill is substituted for a rotary wire brush. This cleans meter parts in a hurry.

The uses of compressed air in a meter repair shop are many. This added convenience in meter shop repair work will speak for itself.

The use of a hand press similar to the press used on electric drills is a sure way of observing the fit of the disc in the chamber before the meter is put together. This eliminates the guess work connected with tight or ill-fitting discs.

An elevated container of gear lubricant is directly connected to a quick opening valve with string attachment. This gives positive control of the amount of lubricant added to the gear train chamber because it closes so quickly—thus eliminating the mess which generally accompanies the handling of gear lubricant.

*Courtesy, E. T. Cranch, Mgr., New Rochelle (N. Y.) Water Co.

WATER METER TESTING PRINCIPLE AND PRACTICE

[*From "Testing Water Meters—Why and How"*]*

The testing of a water meter is very simple. It consists of checking the registration of the meter against the actual volume of water passing through the meter, as measured in an accurate volumetric tank or weighed on accurate scales.

Meter accuracy may be defined as the quotient obtained by dividing the meter reading by the actual volume of water. Thus a meter registering 9 gallons when 10 gallons are run through it has an accuracy of 9/10 or 90%. A meter registering 52 cubic feet on an actual volume of 50 cubic feet is 52/50, or 104% accurate.

Meter accuracy is commonly expressed in percentage fast or slow. Thus a meter which records 95 gallons when 100 gallons are run through it under-registers or is slow by 5%. A meter registering 102 gallons on the same volume would be 2% fast.

Good Practice in Testing

Before starting a test, water should be run through the meter or meters at a high rate, say 10 or 15 gallons per minute, until all the air is out of the meters and the line, and the delivery pipe to the tank is as full or as empty as it will be at the end of the test. Start the test flow with the test hand of the meter or meters on an even starting position or line on the dial. This can be done either by running water from the outlet of each meter until it has the test hand at the proper position, or the register can be turned around in the case until the test hand stands on the line.

When testing one meter at a time with calibrated tank or with scales having percentage beams, the test flow should be stopped when the meter has indicated the passage of the test amount. The percentage fast or slow of the meter can then be read direct from the tank gauge or from the percentage beam of the scales.

When testing several meters in series or when using scales or tanks without percentage markings, the flow should be stopped when the test volume of water has been run into the tank. The percentage fast or slow of the meter or meters can then be computed by dividing the meter readings by the actual amount of water. It will be seen that the computation will be much simplified if the amount of water is one, ten or one hundred gallons or cubic feet. Thus the divisor is one, which makes the meter reading direct in percentage of accuracy. Example: 100 gallons run through the meter; meter reading 96 gallons; meter accuracy 96%, or the meter is 4% slow.

Amount of Water for Tests

All test amounts except on lowest flow or "sensitive" tests should be at least enough to correspond to one complete revolution of the test hand on the meter dial. Often the test hand pinion is not in the center of the circle on the dial and this would introduce an error in reading with partial turns of the test hand. Common practice is to test on the small flows with an amount representing one revolution and on large flows with an amount representing ten revolutions of the test hand. On the other hand, it is possible to get an accurate test on a 5/8 inch meter with ten gallons or one cubic foot and many meter shops do not go beyond this. Of course the greater the amount of water the smaller would be the errors introduced by inaccuracies in readings.

Single or Series Testing

Meters can be tested one at a time or in series. When there are many meters to test there is a worth-while saving in water and time if several meters are tested at once. The number of meters in series or the number of units in the testing machine justified for any condition depend on the number of meters in the system and the frequency of testing. Testing machines or benches for up to 12 meters are in common use.

In series testing the flow can be stopped when the correct amount of water has been run through the meters into the tank, and the accuracy of each meter computed as indicated above. When only a few meters are tested in series it is possible to take advantage of the percentage calibration on the tank or scales by turning off the water when the fastest meter shows a registration of the test amount, reading the percentage accuracy of the meter, starting the flow again and stopping for each meter as it comes up to the desired reading. This method of obtaining the meter accuracy is not considered good practice as it involves changing the rate of flow for every start and stop involved.

Testing with Test Meters

For testing in the field the so-called test meter is convenient and satisfactory if only a rough check is desired. However, a test meter is only a meter and subject to the same variation in accuracy which is characteristic of all disc meters.

Further, a test meter is not positive in the same way as a tank or scales. Testing one meter with a test meter or with any other meter is simply comparing meters and is not recognized in many states which have regulations or laws applying to means or equipment for water meter testing. Field testing can be done much better and more accurately by means of a calibrated testing tank.

Money Value of Meter Accuracy

The accuracy of a water meter is a matter of dollars and cents to the customer and the utility.

Fortunately for the customers, water meters which were originally accurate cannot over-register beyond a slight speeding up in some water conditions. This action is self-limiting, for friction increases with the building up of the disc or piston and tends to counteract the speeding up. Water meters always slow down in service as they become worn, corroded or encrusted.

The intervals at which it is profitable to the water works to test meters and repair them depends entirely on the effects of the water and service conditions in making the meters under-register, on the value of the water taken but not registered, and on the cost of making the necessary tests and repairs. In other words, if the increased revenue from the meter pays a good return on the cost of making the meter accurate, it is simply *good business.*

Several states have recently adopted regulations which specify limits between meter tests in water utilities, both in time and

*A booklet distributed by Ford Meter Box Co., Wabash, Ind.

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DATE PURCHASED STYLE

INSTALLATION RECORD | **TEST AND REPAIR RECORD**

INSTALLED Date	INSTALLED Reading	NAME	ADDRESS	Tap No.	Reasons for Removal	Removed Date	Removed Reading	Date	Rate of Test Min. Flow	Rate of Test Inter. Flow	Rate of Test Max. Flow	Repairs Before Test	Repairs After Test	Total Amt. of Water Passed Before Test	Tested By	REMARKS

Heading for a Suggested Form for Meter Record Card. This Can Be Adapted to Meet the Requirements of Any Meter Shop. Actual Size of Card Is 8½ by 11 inches.

in volume of water. These limits are necessarily broad, as the composition of water and its effect on meters varies widely in any state, and many utilities profitably test and repair more frequently than required. These regulations show the growing realization that meter testing *is* important.

The following table shows the value of water unregistered by meters of various percentages of slowness, with various amounts of water drawn through the meter and with water valued at from 10c to 50c per thousand gallons. These figures can be easily transposed into cubic ft. by recalling that 100 cubic ft. equals 750 gallons.

From the table it will be seen that with water at 10c per thousand gallons the return on the investment of testing and repairing a meter 4% slow will be only 40c with every 100,000 gallons of water drawn through the meter. It would take a large and active service to make frequent testing pay under these conditions.

On the other hand, with water at 50c per thousand gallons a meter failing to register 20% of the water passing through it (not terribly rare) would lose $1.00 for the water works with every 10,000 gallons. With these conditions maintained accuracy will pay a handsome return on the investment.

TABLE SHOWING VALUE OF WATER NOT REGISTERED BY METERS OF VARYING PERCENTAGES OF UNDER-REGISTRATION, WITH WATER FROM 10c TO 50c PER THOUSAND GALLONS, AND WITH THREE AMOUNTS OF TOTAL DRAFT.

	Value of Water Per 1,000 Gallons								
	@ 10c			@ 30c			@ 50c		
	Total Volume Drawn—Gallons x 1,000								
%*	10M	50M	100M	10M	50M	100M	10M	50M	100M
4	$ .04	$ .20	$ .40	$ .12	$ .60	$1.20	$ .20	$1.00	$2.00
6	.06	.30	.60	.18	.90	1.80	.30	1.50	3.00
8	.08	.40	.80	.24	1.20	2.40	.40	2.00	4.00
10	.10	.50	1.00	.30	1.50	3.00	.50	2.50	5.00
12	.12	.60	1.20	.36	1.80	3.60	.60	3.00	6.00
14	.14	.70	1.40	.42	2.10	4.20	.70	3.50	7.00
16	.16	.80	1.60	.48	2.40	4.80	.80	4.00	8.00
18	.18	.90	1.80	.54	2.70	5.40	.90	4.50	9.00
20	.20	1.00	2.00	.60	3.00	6.00	1.00	5.00	10.00

*Under-Registration Percent.

Steps in Testing a Water Meter

[A ⅝inch meter is used as an example. A larger meter would involve the same procedure but would require greater rates of flow.]

1. **Insert Meter in Tester**—Any means of connecting the meter water-tight in the test line is satisfactory but a regular tester is much more convenient.

2. **Flush Meter Out With a Large Flow**—This is to remove air from the meter and line. A flow of ten or more gallons per minute is desirable and should be continued until discharge indicates that all air is out of the line.

3. **Bring Test Hand of Meter to a Mark**—This can be done by stopping the water flow as the hand reaches the mark, or by turning the dial in the meter case if the meter bonnet is removed.

4. **Run a Test at 10 to 15 G.P.M. Running 50 Gallons or 10 Cu. Ft.**—It is desirable to run this much water although more would be just as good or better. Be sure the calibrated tank is empty or the scales balanced before the test flow is started.

5. **Run a Test at 1 to 2 G.P.M. Running 10 Gallons or 1 Cu. Ft.**—Here again the exact amount is subject to variation and more water can be run if there is plenty of time and water.

6. **Run ¼ G.P.M. Test, Running at Least 5 Gallons or ½ Cu. Ft.**—This low-flow test is important for reasons mentioned on pages 9 and 10.

7. **Make a Record of the Tests**—Put down in permanent form the accuracy of the meter at the three rates of flow, date of test and other pertinent information. See suggested record card on the reverse of this sheet.

IMPORTANCE OF TESTING DISC METERS AT THE CORRECT RATES OF FLOW*

By P. S. WILSON[1]

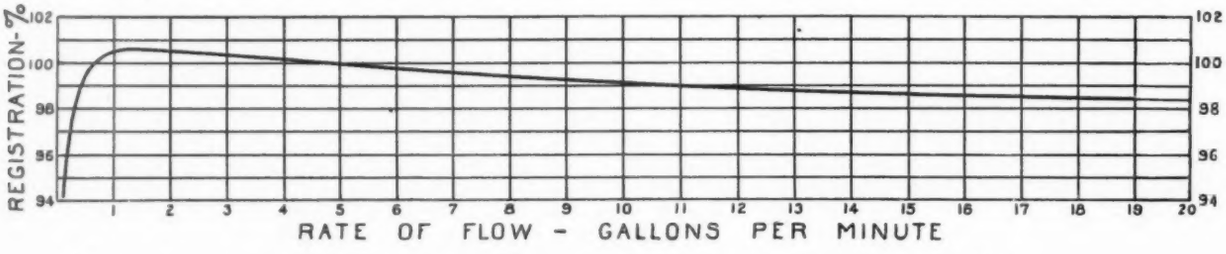
Consultant in Water Works Management, Glen Ridge, N. J.

A typical registration curve of disc type water meters is shown. In this curve the percentage of the water actually registered during passage through the meter is plotted against the rate of flow in gallons per minute.

The curve as a whole may be shifted upwards or downwards by altering the gearing of the meters but this will not change the general shape of the curve. The curve shown in the figure is drawn for five-eighths inch meters but the corresponding curve for any size of disc meter will have much the same shape in relation to the total range of capacity of the meter. The important fact to observe regarding this curve is the fact that it is a curve and not a straight line. In other words, even above the low flows which the meter will not register, the percentage registered is not the same at different rates of flow.

Importance of Testing at Several Rates of Flow

The purpose of testing a meter is to determine the percentage of the water passing the meter which is registered by it. As explained above, this percentage is normally different at different rates of flow. In routine meter shop practice it is of course impractical to test a meter at every rate of flow under which it will actually operate, and yet we must have assurance that it will register within the limits of accuracy adopted at all of these different rates. We know that a test at a single point on the curve, that is, at a single rate of flow, will not give us the percentage registered at other rates of flow. The curve may be of different curvature depending upon the condition of the meter, and we are making the test because we do not know the condition of the meter. If the clearances in the disc chamber are too great, for example, the meter will not register the low flows well and its curve will drop off too rapidly at that end. If the "control" is not close enough, that is, if the spindle is not held at the proper angle, the meter's registration curve will in all probability go up too high at the intermediate rates of flow. With the multiplicity of parts in a



Curve Showing Accuracy of Meter Registration at Variable Rates of Draught

meter there are of course many other defects which may have various effects upon the performance of the mechanism as a whole.

The endeavor must be to test the meter at the least number of rates which will serve to indicate with sufficient reliability what the performance will be over the rest of its range of capacity. It has been found that in normal practice it is necessary to make a test at each one of three different rates of flow, unless the condition of the meter is already quite well known. In order to obtain reliable information from as few as three different rates of test these rates must be carefully chosen in order to show up the true form of the curve and to know that there are no irregularities in it between the points located by the tests.

*From WATER WORKS AND SEWERAGE, January, 1933.

[1]Now Technical Asst. Secy., American Water Works Assn.

The three rates of flow at which a disc meter should be tested are usually termed the "Low" or "Minimum" test flow, the "Intermediate" or "Medium" test flow, and the "High" or "Full" flow.

Minimum Flow Test Requirements

The "Low" or "Minimum" flow test is made in order to determine that the meter does not drop off in registration at any higher rate of flow than economically possible, in other words, the meter must be able to register down to a certain predetermined low rate with sufficient accuracy. The accuracy of registration at low flows depends to a large extent upon the reduction of clearances and at the same time the avoidance of friction in the meter.

The rates of flow called for as "Minimum Test Flow" in the Standard Specifications for Disc Type Meters as adopted by the American Water Works Association and the New England Water Works Association, and reproduced herewith as Table I, are the rates of flow in common use. Different organizations vary somewhat the required percentage of registration at these flows to suit individual views and conditions. The Standard Specifications referred to call for at least 90 per cent registration at minimum test flows. Good manufacturing methods and skillful repair work can be considerably better than this on both new and repaired meters, 94 per cent or 96 per cent being not unreasonable to expect.

TABLE I

Rates of Test Flow. From Standard Specifications for Cold Water Meters, Disc Type, Adopted by the A. W. W. A. June 19, 1921, and by the N. E. W. W. A. Sept. 14, 1921

Size of Meter (Inches)	Normal Test Flow Limits (Gallons per Minute)	Minimum Test Flow (Gallons per Minute)
⅝	1 to 20	¼
¾	2 to 34	½
1	3 to 53	¾
1½	5 to 100	1½
2	8 to 160	2
3	16 to 315	4
4	28 to 500	7
6	48 to 1000	12

Intermediate Flow Test Requirements

The Intermediate test flow should be chosen so as to ascertain that the registration at the high point of the curve does not go too high. The rates should, therefore, be such as to aim for the probable highest point. This will vary with different makes and types of meters but it will usually be found at, or a little higher than, the lower figure given under "Normal Test Flow Limits" in the Standard Specifications—see Table I. For a five-eighths inch meter the table gives 1 gal. per min. and the test flow should usually be from 1 to 2 gal. per min.

If the meter is geared and fitted so as to maintain a good registration at the low and high flows then the difficulty in most cases will be to keep the registration down at the intermediate flow. The flatter that the curve for the meter is, the less need there is for such practice. This is one of the many things to be considered in selecting a meter.

High Flow Test Requirements

The high flow test is considered by some to be the least important. This is unfortunate because it is the quickest and most convenient to perform. The exact rate of flow to be used at this test certainly is less important than with the low and intermediate tests because at rates of flow above the intermediate the curve is not apt to rise or fall so markedly. Many shops use a high test flow equal to the higher figure given under "Normal Test Flow Limits" in the standard specifications (Table I). For a five-eighths inch meter the 20 gal. per min. flow is approximately the maximum rated capacity of the meter. The practical objection to using this figure for the high test flow is that in very few cases will the service pipe and plumbing in a residence pass nearly so high a rate of flow and we are therefore testing at a rate beyond that at which the meter will ever operate. Between 50 per cent and 75 per cent of this high figure is a more logical one to use for testing in routine procedure. At the high flow the percentage registered should again be kept up, as in the low flow, and a minimum of 98 per cent is often specified in accordance with the standard specifications.

Having given consideration to the reasons for choosing each one of the three different rates of test flow it is of course self-evident that it is of equal importance to actually perform the tests at those rates, in other words, to measure with reasonable accuracy just what the rate of flow is during the test and to adjust it to the correct figure.

TABLE II

Discharge of Orifices in Gallons Per Minute. The Smaller of the Two Figures Given in Each Case Is the Discharge of a Sharp Edged Orifice in a Thin Plate. The Larger Figure Is the Discharge with Properly Rounded Edges

Size of Orifice— Inches	———Pressure—Pounds Per Square Inch——— 40	60	80	100
1/32....	0.11— 0.18	0.13— 0.22	0.16— 0.26	0.18— 0.29
1/16....	0.44— 0.74	0.54— 0.90	0.62— 1.0	0.70— 1.2
1/ 8....	1.8 — 3.0	2.2 — 3.6	2.5 — 4.2	2.8 — 4.7
3/16....	4.0 — 6.7	4.9 — 8.2	5.6 — 9.4	6.3 —10.5
1/ 4....	7.1 —11.8	8.7 —14.5	10.0 —16.7	11.2 —18.7
5/16....	11.1 —18.5	13.6 —23.	15.7 —26.	17.5 —29.
3/ 8....	16.0 —27.	19.6 —33.	23. —38.	25. —42.
7/16....	22. —36.	27. —44.	31. —51.	34. —57.
1/ 2....	28. —47.	35. —58.	40. —67.	45. —75.

Importance of Accurately Measuring Flows

The most frequently used means of determining the rate of test flow is with an orifice. No fault can be found with this means if we really know how much water is flowing through the orifice.

The rate of flow through an orifice of a given size depends principally upon the shape of the edges of the hole, the thickness of the plate in which the hole is drilled, and upon the effective pressure acting to push the water through the hole. Rather than to state the size of the orifice it is far more definite to give the rate of flow in gallons per minute, or as the number of seconds to pass one cubic foot, as is done in up to the minute shops.

Table II gives the uncertainties of using orifices which have not been actually tested under fixed and known pressures. For example, a one-sixteenth inch orifice under a pressure of eighty pounds per square inch may discharge as much as one gallon per minute if the inner corners of the hole are properly rounded. On the other hand if the edges of the hole are sharp and square and the plate through which the hole is drilled is thin the discharge may be less than two-thirds of a gallon per minute under the same pressure. Variations in the effective pressure added to the above uncertainties will of course cause even greater indefiniteness in the discharge. At forty pounds per square inch the discharge of the one-sixteenth inch sharp edged orifice may be considerably less than one-half gallon per minute, while an increase of the pressure to one hundred pounds per square inch will produce a discharge through the same orifice with rounded edges of over two and one-half times as much. Such uncertainties as these will greatly nullify the benefits of otherwise careful testing.

The best way to determine that the correct rate of flow is being used is to actually use a watch, and preferably a stop watch, to time the filling of a calibrated can or tank. The test flows should be stated in terms of definite figures, such as gallons per minute, and not in terms of the size of the orifice or the number of turns of the valve wheel.

The figures given in Table II are the theoretical figures as to the discharge in gallons per minute of different sizes of orifices under different pressures. The smaller of the two figures given in each case is the discharge with a sharp edged orifice in a thin plate, or with the edges properly bevelled on the outlet side. The larger figure is the maximum discharge to be expected with properly rounded edges on the inlet side of the orifice plate. These figures may serve as a guide in the choice by trial sizes of orifices to be used for obtaining certain rates of discharge. Actual measurement and timing should be employed to check each one, however. It must be remembered that the pressure which is effective upon the orifice will only be shown correctly by a gage located next to the orifice, and beyond the meter being tested, also that the pressure reading must be taken after the flow has become steady and constant.

SELECTING THE RIGHT METER*

By ROGER W. ESTY**

Superintendent, Danvers Water Works, Danvers, Mass.

In days gone by, the thought of "What shall we set for a meter on a service line?" was not given the consideration warranted. The expense involved apparently did not appear to be a factor, because the size of the pipe installed was generally used as the determining factor in selecting the size of meter for the installation.

Since those days meters have reached a much higher degree of perfection and now, at reasonable cost, meters can be purchased to fit any service required; and, can be depended upon to give satisfactory results.

Especial care should be exercised when purchasing a meter because this device serves as the cash-register of the system. When purchasing a meter do not let the price be the determining factor; for, as you know, the older we get the more and more do we realize that you get just about what you pay for. There is no such thing, nowadays, as truth in a claim that "It is just as good for one-half the price."

We must not forget the obligation we owe to those we serve. We must not spend their money recklessly or unwisely.

Several years ago, at Danvers, we had a water waste survey made to check up on our consumption, which apparently was gradually creeping upward without any particular reason. Much to our surprise, we found no unreasonable leakage, but found that all of our large meters were under-registering, some as much as 50 or 60 per cent. On large meters this constitutes a sizeable and serious loss.

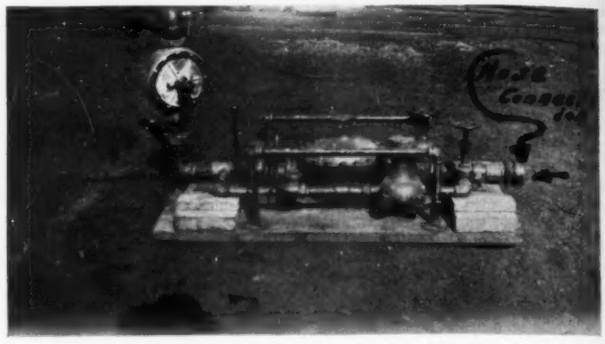
In the past, we never tested these meters. And, as long as they kept running and the monthly readings were comparative little, if any, attention was given them. When we found a stopped one we would take it apart and clean it and make whatever repairs found necessary. We didn't know whether the meter recorded accurately or not. We merely assumed that if it was properly cleaned and repaired it must be right.

After our water waste survey we changed practically every meter. Some we had rebuilt. As time went on we found that this change had been very unsatisfactory. We were suspicious of the accuracy of the readings of one large meter, realizing that its registrations must be too low. To obtain a test on it, we put in two one-inch corporation checks, brought them together, and then from this junction extended a fire hose to a two-inch test disc-meter which had been previously checked for accuracy. From this set-up approximately 200 g.p.m. was obtainable. Apparently our suspicions had been right because we found the meter under-registering. As a result of that test, we started tapping in just beyond all of the other large meters for additional testing.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, Sept., 1934.

**The author has the distinction of being now (1936) President of N.E.W.W.A.

Neptune Recording Meter Set, Used in Evalulating Variations in Water Takings by a Customer and Determining the Proper Capacity of Meter



Portable Meter Testing and Flow Measuring Outfit Used in Field Tests

Meter By-Pass Lines Proved Their Worth

From the results of this work, we decided to take out all of our institution and industrial meters, replacing them with new meters. In each case we provided a by-pass line, a test tee and the necessary gates, so that tests and repairs could be made at any time without inconvenience to the customer.

In my opinion the money spent constituted the best investment we have ever made for convenient and money saving maintenance. It is a highly justifiable expense and no meter of any consequence should be set without being provided with a properly gated by-pass with a test plug inserted.

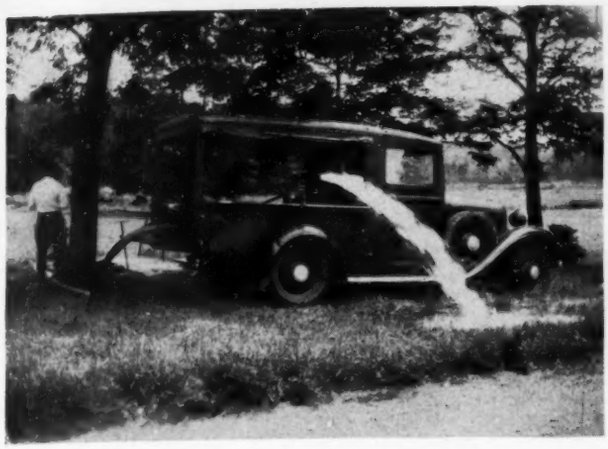
We made mistakes in our first set-up that I would correct if I had to do the work over again. In making changes my first correction would be to set the meter on the by-pass, line and leave the main line unobstructed, to take care of large emergency demands such as would be needed at a fire. As a general rule, a meter much smaller than the size of the supply pipe can be, and should be used and there is also a saving to be had in the cost of the smaller fittings required. This is now the practice followed in Danvers.

Then, next, all gates should be provided with rising stem valves. There is a possibility of leaving gates opened or closed where the standard (non-indicating) gate stem is used. Visualization is a great safeguard and protection and at a glance one can tell the position of a rising stem valve.

Oversize Meters—Why?

After this new set-up of meters had been in for a few years, we made a 3 or 4 day test on each meter, running the recording testing device twenty-four hours each day. The results were surprising—even astounding. Meter line requirements on 6 and 8-inch pipe lines, provided with meters of the same size as the pipe, showed that at no time did the demand exceed on the 6-inch meter 25 g.p.m. and on the 8-inch meter 75 g.p.m.

From these results it was apparent that: In the first case a ¼-inch meter would amply take care of the normal demands on the 6-inch service; and in the second instance a 1¼-inch



Portable Meter Testing Outfit on Service Wagon. Connection Is Made by Fire Hose to Meters Tested

meter would suffice on the 8-inch service. But, these meters were on lines supplying hydrants, and therefore the smaller meters could not be used. It is my opinion, however, that a 4-inch meter—if not a 3-inch meter—will prove ample. A 3-inch meter on a by-pass will supply two powerful fire streams and in most cases this will be sufficient. If a greater demand should be required the main line can be opened. Since we have a man who answers every fire alarm, he has been instructed in every instance to open up the gate on the unmetered side, regardless of how small the first might be.

We have had these smaller meters in now for nine years and we have only opened up the unmetered side of the line once. At this fire only one stream was used, but the gate was opened just the same. No difference was noticed in the volume in this instance, where a 3-inch meter had been cut into a 6-inch line leading from an 18-inch main.

What Size Service Line?

When laying a service main I thoroughly believe in laying one that will more than take care of the service demanded. Larger lines reduce friction and deliver volume up to the point of the demand. The owner should be interviewed regarding what he feels will be his maximum demand in gallons per minute. On commercial lines, I try to have the customer visualize a barrel and then tell him that that barrel holds 50 gallons. Then I ask, how much more or less than 50 gallons per minute will he use? He can readily make a comparison in his mind between the 50 gallons and the amount he is going to use and he can then easily judge about how much he will use, and it is seldom you will find any user using more than "a barrel a minute." Cubic feet means nothing to the customer, and even gallons per minute means little, but the barrel method of determining the amount of water he might use, is much easier for him to understand and has not failed yet in giving to me the information that I have wanted in determining the size of meter and service needed.

The type of service and demand, should be instrumental in determining the type of meter that should be used. Consideration of the small flows should be given prior consideration because 90 per cent of the flows come under the range of the smallest capacities of the large meters. If a large continuous flow is used, then naturally a meter to register large flows should be used as there are no small streams to be considered.

I have a case in my own system, at Danvers, where all of the water is repumped and this pump operates at about 500 g.p.m. until the tank is full, then it automatically shuts off and no more water passes through the meter until the level of the tank drops sufficient to kick in the automatic pump switch. In this case a meter to pick up minor flows, leakage, etc., is not needed, because the rate of flow is 500 g.p.m. or nothing.

The selection of the meter, should in my opinion, be left with the water works officials and *not* to the customer. The ownership of the meter should also be retained by the water department and *not* by the customer. By experience, water works managers are much better qualified than anyone else to select the proper meter which, in justice to all, must be the most adaptable to the desired type of service it is selected for.

Renovating Water Meters

Water Companies, on the whole, and also several of the more progressive municipally owned Water Departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, Superintendent of Meters in the Water Department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid—to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

METER TESTING, REPAIR AND SELECTION

By CLEM. A. GALLAGHER

Superintendent of Services, Louisville Water Co., Louisville, Ky.

Recently while making a trip for the purpose of inspecting various meter shops throughout the country, one basic and sad truth struck me bluntly.

That sad truth is simply this: Despite all the progress made in the waterworks field in filtration, pumpage, construction and billing, yes, even in the meter field, a paradox still confronts us. The one sure-fire revenue producing instrument is seemingly neglected, if not ignored. Less, generally, is known about water meters than about any other essential waterworks mechanism. I am of the firm opinion that a definite, efficient, and consistent meter testing and repairing program is a vast asset to any Water Department or Water Company. The revenue accruing naturally from such a program will more than pay the initial expenditure for such a program in the first few years. The difference between 85 per cent and 100 per cent seems not so large arithmetically, but in just one service in one year's time it means many dollars and cents in any language.

Contrary to popular belief a meter testing and repair program is simple in itself. And the cost of such has been grossly exaggerated. By explaining simply, and somewhat in detail, the meter plan we have been working successfully and at reasonable cost in the Louisville Water Company, I hope to prove my contention that a definite, efficient, and concise meter testing and repair program is a vast and lasting asset to any water utility, irrespective of size. Further, that such a program can easily and reasonably be inaugurated and maintained.

The Four Phases of the Program

In such a definite program four phases comprising the composite must be considered and I shall treat of them in order. Meters must be exchanged, tested, repaired. Then, records must be kept of all these operations. It stands to reason that any system which would insure an unfailing and accurate record of a meter, from the time it left the ground until it was returned after testing and repair, would be the most desirable method from every standpoint.

This is our method: We have three men with small trucks exchanging meters daily and returning them to the shop. These men likewise take care of all meter complaints such as meters stopped, broken counters, leaks, etc. Normally each man and his helper will exchange about thirty-five meters a day. A card (here illustrated) has been devised to take care of all of the recording. This card is perforated midway and entwined with a wire at the top. The cards are numbered, and used and filed consecutively. On one side of the card at the top is a record for the meter reset after it has been repaired, tested and O. K.'d. Space is available for the make of meter, the serial number, size, the address set, the attachment number, the account number, the date set. It is signed by the man placing the meter back in the ground.

The lower half of the card on the same side has the record of the meter removed with make, serial number, size, reading, address removed from, attachment number, account number, date removed, reason for removal (exchange, frozen, out of order, etc.), and also space for the signature of the man removing the meter.

On the other side of the card the upper half is blank while the lower half contains a complete record of the meter test and repair. Each meter coming into the shop has this attached card wired to the casing so that this same card remains with that one meter from the time it leaves the ground at one location until it is returned to the ground in another place. This obviates the danger of lost cards and garbled records.

Each meter received in the shop is tested as received and tested, as final, after it has been repaired. Each meter is thoroughly cleaned and repaired irrespective of its first test average. Each 5/8-inch meter is tested with fifty gallons at ten gallons a minute and with ten gallons at one gallon a minute. The meter tester places both percentages on his card as well as the average of the two. The meter is then sent to the repair bench to be cleaned and repaired.

Thorough Shop Records

The lower half of this part of the card contains a list of the repairs made, parts replaced, and the time consumed in this

Meter Repair Shop, Louisville, Ky., Water Works

Inertol

INERTOL COMPANY, Incorporated

401 Broadway, New York City

Western Branch:
447 Sutter Street, San Francisco, Cal.

Where and How to Use Inertol Products in WATER WORKS

1. ON ALL CONCRETE IN CONTACT WITH WATER BUT NOT VISIBLE: for "tile-surfacing" the walls of filter beds below the sand line, for waterproofing covered reservoirs and basins, for eliminating slime and accelerating the flow in tunnels, conduits, flumes. Apply INERTOL STANDARD #49 in 2 coats, at the rate of 1 gallon for 200 square feet, each coat.

2. ON ALL CONCRETE IN CONTACT WITH WATER AND EXPOSED TO VIEW: for "tile-surfacing" the walls of filter beds above the sand line, for waterproofing coagulating basins & clarifiers, for eliminating slime and retarding algae in flumes, channels and open conduits. Apply RAMUC ENAMELS as per color chart, in 2 coats, at the rate of 1 gallon for 200 square feet, each coat.

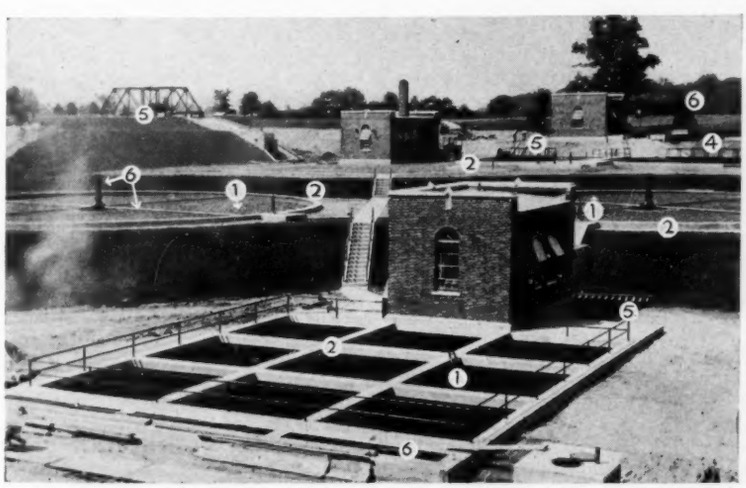
3. ON ALL CONCRETE BRICK OR PLASTER ABOVE WATER: for protection against condensation of water and chemicals and for decorating floors, walls and ceilings of pump stations and filtration plants with a clean, non-peeling and washable finish. Apply RAMUC ENAMELS as per color chart, in 2 coats, at the rate of 1 gallon for 200 square feet, each coat.

4. ON ALL IRON, STEEL OR WOOD SUBMERGED UNDER WATER: for durable protection against corrosion of wash water troughs, stand pipes and tanks (inside), chemical feeding troughs, etc. Apply INERTOL #55 (black) in 2 coats, at the rate of 1 gallon for 300 square feet, each coat. On rough, very absorbent or brand new surfaces use first a priming coat of INERTOL #50 STEEL PRIMER, applied at the same rate.

5. ON ALL IRON, STEEL AND WOOD ABOVE WATER: for protection against condensation of water and chemicals as well as general atmospheric conditions on structural steel in filter plants, pipe galleries, on motor housings, pumps and valves, hydrants, etc. Apply GLAZOFLEX ENAMELS as per color chart, in 2 coats, at the rate of 1 gallon for 300 square feet, each coat. On rough, very absorbent or brand new surfaces, use first a priming coat of GLAZOFLEX PRIMER, applied at the same rate.

6. On CONCRETE, BRICK AND STUCCO EXPOSED TO DRIVING RAINS AND SEVERE WEATHERING CONDITIONS: for waterproofing and frostproofing of outside building walls, aerator walls, spray ponds, etc. Apply PLUVOL (transparent) in 3 coats, at the rate of 1 gallon for 400 square feet, each coat.

In SEWAGE PLANTS



1. ON ALL CONCRETE BELOW SEWAGE LEVEL: for "tile surfacing" all concrete in contact with unsettled sewage. Apply INERTOL STANDARD in 2 coats, at the rate of 1 gallon for 200 square feet.

2. ON ALL CONCRETE ABOVE SEWAGE LEVEL: for frostproofing, acidproofing and as a decorative finish, also as a protective coating against chlorine and hydrogen sulphide on floors, walls and ceilings. Apply RAMUC ENAMELS in 2 coats, at the rate of 1 gallon for 200 square feet, each coat.

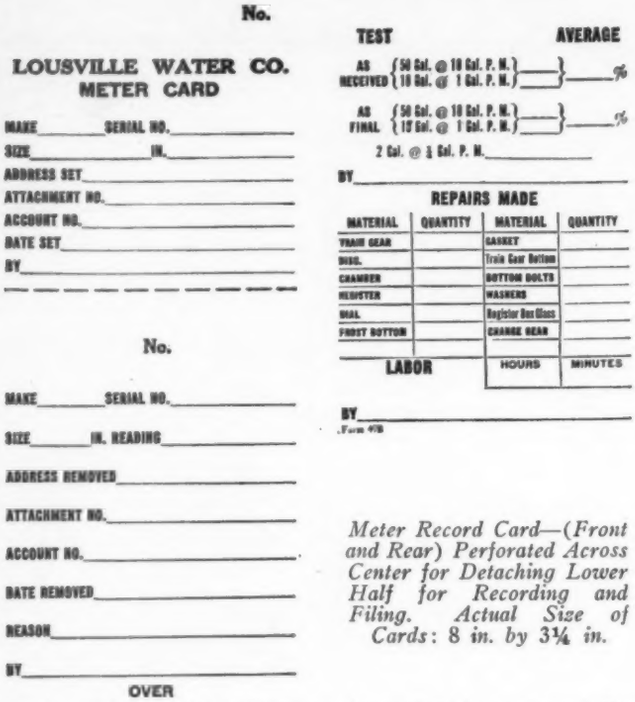
3. ON SMOOTH IRON OR STEEL BELOW SEWAGE LEVEL OR IN MOIST ATMOSPHERE: for durable protection against sewage and condensation. Apply INERTOL STANDARD in 3 coats, at the rate of 1 gallon for 400 square feet, each coat.

4. ON SHARP EDGED, ROUGH STEEL BELOW SEWAGE LEVEL: for durable protection of thin steel sections, regardless of edges, corners and angles. Apply 2 coats INERTOL STANDARD at the rate of 400 square feet per gallon and 1 coat of INERTOL STANDARD THICK at the rate of 200 square feet per gallon.

5. ON ALL IRON AND STEEL SURFACES ABOVE SEWAGE LEVEL: for durable protection and beautiful appearance of steel surfaces exposed to strong abrasion, sewage mist, sun and gases, indoors and outdoors. Apply GLAZOFLEX ENAMELS, as per color chart, in 1 or 2 coats over GLAZOFLEX PRIMER, at the rate of 1 gallon for 300 square feet for primer and finish coats.

Spalling or rough concrete is hard to keep clean. Rusting equipment causes all kinds of trouble. A well kept plant is more easily run! Inertol Products will save you many hours of work and make your water works and sewage plant clean, sanitary and attractive.

INERTOL RAMUC ENAMEL



No.

LOUSVILLE WATER CO.
METER CARD

MAKE_____SERIAL NO._____
SIZE_____IN._____
ADDRESS SET_____
ATTACHMENT NO._____
ACCOUNT NO._____
DATE SET_____
BY_____

No.

MAKE_____SERIAL NO._____
SIZE_____IN. READING_____
ADDRESS REMOVED_____
ATTACHMENT NO._____
ACCOUNT NO._____
DATE REMOVED_____
REASON_____
BY_____

OVER

TEST AVERAGE

AS RECEIVED { 50 Gal. @ 10 Gal. P. M. / 10 Gal. @ 1 Gal. P. M. } ____ } ____%

AS FINAL { 50 Gal. @ 10 Gal. P. M. / 10 Gal. @ 1 Gal. P. M. } ____ } ____%

2 Gal. @ ½ Gal. P. M._____

BY_____

REPAIRS MADE

MATERIAL	QUANTITY	MATERIAL	QUANTITY
TRAIN GEAR		GASKET	
DISC.		Train Gear Bottom	
CHAMBER		BOTTOM BOLTS	
REGISTER		WASHERS	
DIAL		Register Box Glass	
FROST BOTTOM		CHANGE GEAR	
LABOR		HOURS	MINUTES

BY_____

Form 478

Meter Record Card—(Front and Rear) Perforated Across Center for Detaching Lower Half for Recording and Filing. Actual Size of Cards: 8 in. by 3¼ in.

repair. The material is listed on the card with a corresponding space for the quantity of each part used and the bin number from which it was taken. As a consequence, each man while repairing a meter must put down just what new part, or parts, he used, how many parts were used and how long it took him to finish this one meter. The meter repair man then signs the card and the meter is returned to the testing table. It then goes through its final test of fifty gallons at ten gallons a minute; of ten gallons at one gallon a minute, and of two gallons at one-fourth gallon per minute as a final check. The averages are again noted and averaged and this part of the card is then signed by the chief meter tester. If the meter does not register within two per cent it is returned to the bench for a further overhauling. If it, however, registers accurately the card is then severed at the perforation marks and the lower half returned to the meter record office. This card contains, therefore, for the clerks in the meter record department, complete information in regard to this one particular meter including the removal of the same with all statistics, the testing of the same and the repairing of the same. The signature of each foreman definitely places responsibility for errors under each classification. The information from these cards is transcribed to the regular permanent meter cards and the shop tag cards are then filed, according to their test number, in a file to fit this card. This gives the department a test and repair file.

Our endurance test box in the basement is so constructed that it will hold twenty-five meters at one time. It is arranged in a series of two boxes and any meter of any series, either series, or both, can be removed at any time by means of valves without affecting the flow of water in the building. Our figures in many of these tests have been most startling, and seem to prove one thing very conclusively—that the A. W. W. A. specifications for ⅝ inch cold water meters are entirely too lenient. A well constructed water meter should register much better than 90 per cent on a one-fourth gallon per minute stream.

We recently made a meter under-registration survey. We brought into the shop at one time three hundred meters which had been in service five years or longer and tested them as received. The averages were startling inasmuch as the average percentage of inaccuracy on flows for all meters up to and including the one-fourth gallon per minute flow was far above standard requirements, for new meters.

It has been our endeavor in this entire meter program to aim first at thoroughness, but thoroughness through simplicity. We believe we have accomplished our goal and through the cycles described in this paper are able to test and repair water meters regularly, accurately, efficiently and economically. The cost of this program will be as nothing compared with the revenue pickup naturally consequent on such a program—not to mention the life added to the meters.

Any water utility, which neglects to maintain a definite regular meter test and repair program is neglecting what should be considered a water company's greatest asset. As the meters go—so goes your revenue. A water meter *can* be tested, repaired and kept in shape. Like anything else in life, so with water meters—the simplest and safest way is the best and the cheapest way.

The top half of the card remains, of course, on the meter until that meter is again taken out to be reset. Then in like manner the man resetting tthis meter or exchanging it for another fills out the information given above, disconnects the wire and card from the meter, signs the card and returns this reset information to the meter record department. We thus have a complete cycle for our exchange program and by the use of this simple card we have not only a method of double checking each step but also of definitely placing responsibility where it should be placed.

This exchange system, simple as it is, has worked out most successfully for us and should do so for others. The men exchanging meters take out each day just as many tested and repaired meters as they will exchange. This cycle keeps the shop free from meters piling up. At our present speed each of our 50,000 meters will be put through this process once every five years, although our tests (with our water and our meters) show that this period between tests for economy reasons should be lengthened appreciably.

Testing

Next we come to the testing of a water meter. As I have explained above, a meter is tested as received and again after repairs. The size stream for the test depends, of course, upon the size of the meter.

Our meter testing table can test ten ⅝, ¾ or 1 inch meters at a time. On an adjoining bench the larger meters, up to six inches, are tested one at a time. We have done away with the slower method of weighing for tests, and use only calibrated tanks and funnels. A hydraulic plunger keeps the meters in place. This test bench is so arranged that we can vary our stream anywhere from 225 gallons per minute down to 1/320 gallons a minute. The latter is accomplished by means of needle valves.

Recently we have standardized on the sweep-hand dials on all meters, for two very definite reasons. First of all it is much easier to detect a leak on any size meter if it is equipped with a sweep-hand dial, and secondly and even more important, it facilitates the testing of a meter in time saved and assures us that our registers are likewise accurate. We could not be sure of this by the use of test dials. Our meter tester and his helper average over one hundred ⅝ inch meters per day on standard tests. A cycle is likewise completed here, since in the morning meters are tested as final and in the afternoon a new lot is received. Thus the repair men on the bench, work each day on the meters tested as received the previous afternoon while the meter tester tests as final in the morning the meters repaired the previous day.

It is noteworthy that our records show that less than one percent of the total number of meters repaired have been unfit after repair, and have to be returned to the bench. The promiscuous use of change gears is undesirable and we try to get away from it as fully as possible.

Repairing

The next step in our meter routine is our repair bench. Five men work on this bench and each man has his own set of tools, his own sink with running hot and cold water, his own brushes and a hose with a stop-valve carrying compressed air of about seven to ten pounds pressure. This air is simply piped from our garage and reduced in the meter shop by means of a reducing valve. We have found that this compressed air at this pressure is most useful and practical for testing out the running smoothness of a meter as well as ejecting particles which may be holding back the best performance of a meter. It likewise does away with the necessity of the men placing their mouths on the outlet or inlet to a meter.

The meter bench is made of wood and covered with heavy galvanized iron. Above each man is an electric reflector which evenly lights up his place of work just where he needs it most. Each meter is placed in a separate pan to do away with the loss or mixing up of parts.

Our manner of cleaning a meter is simply the old fashioned but effective soap and water method. We deprecate the use of acid on any meter, or parts thereof, unless it is absolutely necessary. We have found that under our own water conditions the encrustation can be satisfactorily and more safely removed by good old hot water, soap, and elbow grease. We do no machining or reboring because, generally, replacement is cheaper and safer from every angle. Above the repair benches are marked and lettered compartments for the various parts of any

STREAMLINE PIPE AND FITTINGS DIVISION
MUELLER BRASS CO.

Port Huron, Michigan

STREAMLINE Copper Pipe and STREAMLINE Solder Fittings for Water Service Work

In 1924 the Mueller Brass Co. originated and were the first to introduce a product then known as Mueller Copper Service Pipe and Flared Fittings. This was a distinct innovation and was conceded to be the most revolutionary contribution of the time for water service purposes.

Waterworks' engineers and superintendents prefer as soft copper pipe as possible for water service work. STREAMLINE Type K Pipe is consistently and uniformly soft. It is made from Virgin Copper Ingot consisting of at least 99.94% copper and throughout every phase of its manufacture is under rigid and constant laboratory control. From the time we started to manufacture this product in 1924, and throughout the years since, we have produced the best and the softest pipe that can be made for water service work.

RUST PROOF

STREAMLINE Copper Pipe is rust-proof and is superior to any other metal for service pipe work. Under normal conditions of soil and water, it will last for generations, and will deliver its full capacity of water free from foreign particles as clear and pure as it is in the water main.

FLEXIBLE

STREAMLINE Copper Service Pipe is exceptionally and uniformly flexible. It can be very quickly and easily bent around comparatively sharp radii without annealing or loading. It may easily be bent around obstructions encountered in the trench with a great deal less cost than would be entailed in removing the obstruction.

REASONABLE COST

Copper Pipe connected with STREAMLINE Fittings is very reasonable in cost, although naturally a little more expensive than rustable pipe. It really costs a great deal less over a period of time, because replacements are eliminated owing to the rust and clog-proof properties of STREAMLINE Type K Copper Pipe.

COUPLING
Copper to Copper

VIBRATION PROOF

STREAMLINE Copper Pipe connected with STREAMLINE Solder Fittings is free from the harmful effects of vibration. Vibration is not localized at the joints as it is with threaded or flared fittings, but is harmlessly dissipated throughout the service line.

PERMANENT

STREAMLINE Copper Service Pipe is permanent. Once installed it may practically be forgotten; it will give no future trouble. For years it will continue to give the same uninterrupted service and undiminshed flow of water.

COUPLING
Copper to Iron

SETTLEMENT AND FROST ACTION

STREAMLINE Copper Service Pipe is so ductile that it will stretch enough to easily take care of any settlement of filled earth, or, in fact, anything that might impose a strain on the service line which would cause failure of rigid ferrous pipe or, at the very least, cause leakage at the threaded connections.

TEE

In the Northern States and in the Dominion of Canada, copper service pipe of our manufacture has an outstanding advantage that places it far in advance of any other service material. This advantage is its resistance to frost action. This service pipe containing water under almost any range of pressure used in water service work can be alternately frozen and thawed out for a considerable number of times without showing any effect except a slight increase in diameter.

STREAMLINE SOLDER FITTINGS

The STREAMLINE Solder Fitting is connected to the pipe by feeding solder through a feed hole in the fitting. Capillarity causes the solder to thoroughly bond the pipe to the fitting and produces an enormously strong joint. This joint is so strong that if, for instance, two ¾" sections of pipe are connected with a ¾" coupling and pulled in the Olsen Testing Machine, it requires approximately 9000 pounds per square inch before a failure occurs, and this failure is always in the pipe itself, and not in the joint. This is, of course, far beyond anything it would be required to stand under actual service.

ELBOW

COUPLING
Copper to Inside Thread

A copy of Catalog W-3, fully illustrating and describing these products, together with simple instructions for connecting, will be sent upon request.

STREAMLINE Fittings are manufactured under Patents 1,770,852, 1,776,502, 1,890,998.

size or make of meter. This is part of our permanent running inventory system. Each closed bin contains a different part and each bin is numbered. When the men need any new part for any meter they must mark on their ticket the number of such parts used as well as the bin number from which it was taken. A regular inventory clerk can thus keep, from these cards, a daily record of just what parts were used and how many of each part remains in stock. He has a standard minimum of each part that should be kept in stock. He can daily or on a moment's notice notify the department head just what parts are needed and how many of each, and they are then requisitioned and ordered. Again this inventory system, though simplicity itself, affords an easy check on costs, new parts required, etc.

Each man averages between fifteen and twenty meters a day, completely cleaned and repaired. The average cost, not including overhead, runs about fifty cents a meter for tests and repairs. We use about fifty new discs a month. Bottom bolts and gaskets most often need replacement. A meter is scrapped only after it is completely a liability. We have returned to service meters, after overhauling and cleaning, which have been in the ground forty years and more. One man at another bench takes care of the registers, setting back to zero, lubrication, etc. We solder the counters and thus avoid ruining the gears by running counters back speedily with a motor driven disc. After cleaning, the registers of all meters are then dipped in hot oil and drained. This oil is fine, and not too thick for frigid weather. The meter shop is kept clean and each man knows just what he must clean up before he leaves. The work has been divided. The floor is waxed and a heavy, linked rubber carpet stretches all along the repair and test benches. On Saturday of each week larger meters, from one inch to six inch, are tested and repaired. Of course this work is slower and more tedious than that on ⅝ inch meters. A healthy spirit of competition, a desire to keep the meter shop clean and a pride in repair average, can work wonders if engendered and encouraged.

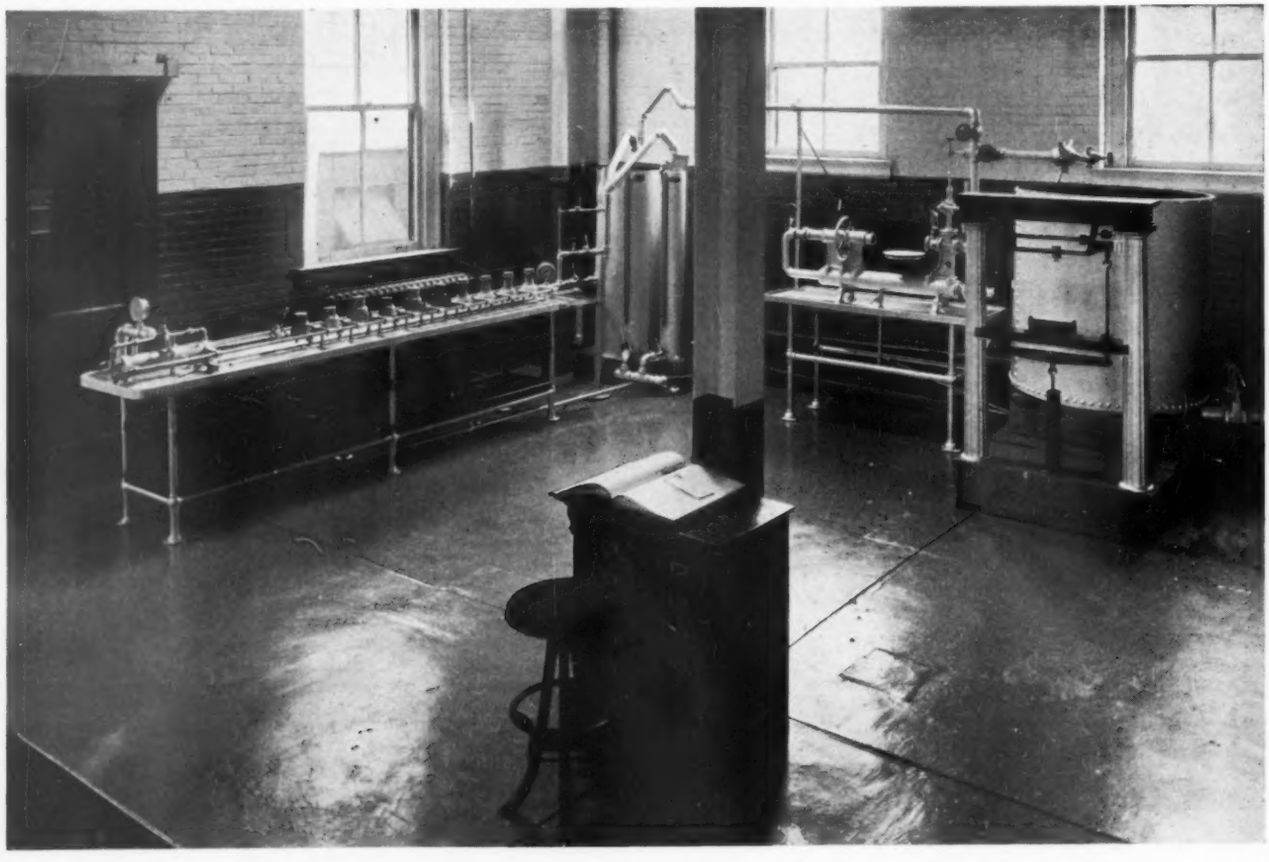
Meter Recording Office

On the same floor is our enclosed meter record office. The head of the Meter Department and clerks keep all records of all meters. We keep two cards on each meter—one according to make and serial number and one according to the book and page number in the meter readers' books. All information—address, make, size, serial number, purchase date and price, sets and resets, tests and repairs, are kept on these cards. Any information concerning any meter in service at any address, any meter in the stock room, or in the shop, is available at all times. The city is divided into districts, lettered alphabetically, and a reference from card to meter books gives all information concerning reading, leaks, etc. The two sections of the numbered cards are filed separately after the information thereon has been transcribed to the other set of cards. These test and repair cards give the final shop information on any particular meter. This system of checks and balances assures accuracy, permanency, and simplicity. All necessary information is always at hand and any meter can be traced from the moment we receive it until we scrap it. We are at present about 75 per cent metered and have in the ground approximately 50,000 meters.

Selecting Meters

When purchasing a water meter three things must be taken into consideration, namely, accuracy, endurance, and interchangeability. It was our desire to find out just what meters would be most dependable under Louisville water conditions and with this idea in mind we have been conducting a series of tests with new stock meters. Ten of each make are tested at a time. The new meters are tested, as received, on flows of ten gallons a minute, one gallon a minute, one-fourth gallon a minute and one-twelfth gallon a minute. These same ten meters are then placed in an endurance test box in the basement and the water used in our building allowed to run through them until they register an average of five hundred thousand (500,000) gallons. We can vary this flow in the building as desired.

They are then taken back to the shop and retested exactly as above. The figures are then averaged, with emphasis on the average percentage of inaccuracy, and blue prints are made of the records for permanent filing Next, these meters are taken apart and thir parts interchanged. They are run then for approximately one hundred thousand gallons and retested again according to the former specifications. Finally they can be run on an absolute endurance test, which of course takes time, until one or more meters in any series breaks down. Faulty meters are taken apart and the cause of such break down investigated.



Testing Benches and Equipment, Meter Shop, Louisville, Ky., Water Works

LIQUID CHLORINE*

Properties of Chlorine

Chlorine is never found free in nature. Gaseous chlorine is manufactured by the electrolysis of a sodium chloride solution. It is then purified and liquefied by a process of compression and refrigeration. As an article of commerce, chlorine is an amber-colored liquid approximately one and one-half times as heavy as water. It is marketed in steel containers which are under pressure. In Fig. 1 is shown the relation between temperature and vapor pressure.

When the pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is approximately two and one-half times as heavy as air. Chlorine is non-inflammable, non-explosive, and a non-conductor of electricity. Generally speaking, in the absence of moisture it is not corrosive to common metals. In the presence of moisture gaseous chlorine reacts avidly with a majority of known substances.

Following is listed the more important chemical and physical properties of chlorine at standard conditions (32° F. and 1 atm. pressure) unless otherwise noted:

	Atomic	Molecular
Chemical Symbol for Chlorine....	Cl	Cl_2
Chemical Weight Relationship...	35.457	70.914
	Gaseous Chlorine	Liquid Chlorine
Specific Gravity	2.49* (air = 1)	1.47† (water = 1)
Weight per Cubic Foot...	0.201 lb.	91.70 lb.
Volume per Pound	4.98 cu. ft.	0.011 cu. ft.
Specific Heat		0.2230†
Liquefying Point		— 28.5° F.†
Freezing Point		—151.6° F.‡
Latent Heat of Evaporation		121.0 B.t.u.†
Critical Temperature		294.8° F.†
Pressure at Critical Temperature		1233 lb. per sq. in.
1 Volume Liquid		456 vol. gas

*Leduc †Kneitsch ‡Lange

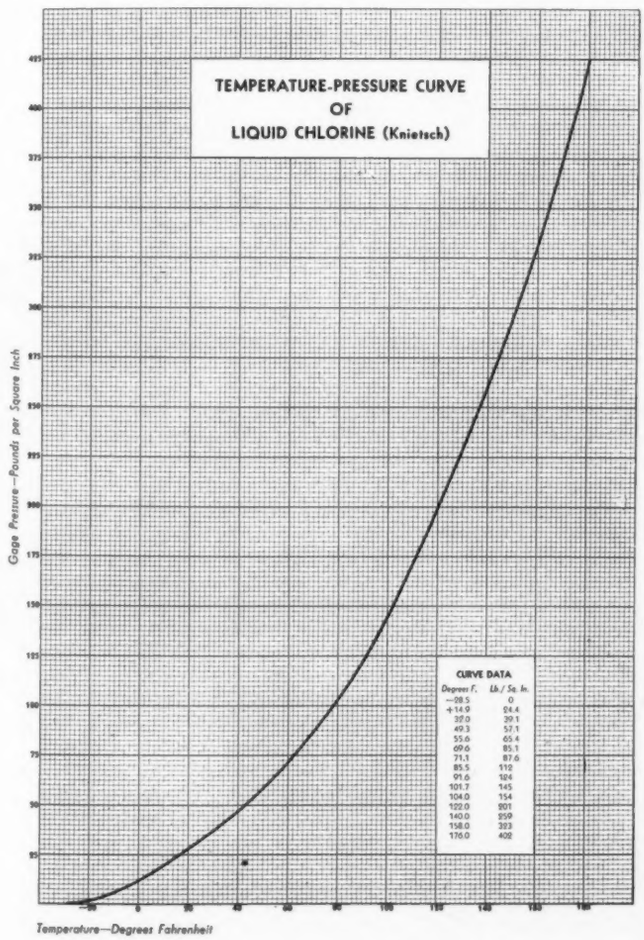


Fig. 1—Relation between Temperature and Vapor Pressure

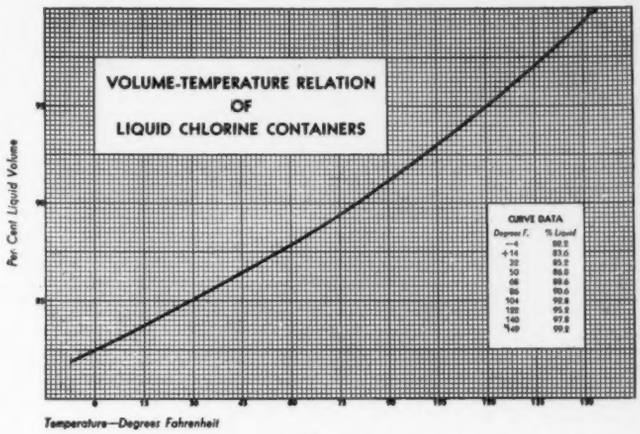


Fig. 3

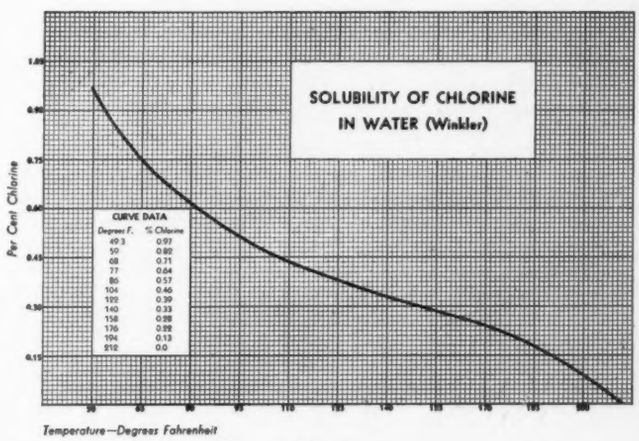


Fig. 4

A better visualization of those properties which are more serviceable can be obtained by studying the following charts and tables.

The compressibility coefficient of liquid chlorine is more than that of any other liquid element (approximately 0.0118% vol. /atm.). Its density decreases quite rapidly with increasing temperature. It is obvious from an examination of Figure 3 that above 156° F. a cylinder loaded to legal limits is subjected to hydrostatic pressure which will rupture it. Therefore, it is most important that the cylinder be kept safely below this temperature in any circumstances.

Chlorine is only slightly soluble in water. As depicted by Figure 4, its maximum solubility in distilled water is approximately 1% at 49.2° F. Below that temperature chlorine crystallizes in the form of chlorine hydrates, their composition depending upon conditions.

Liquid Chlorine Containers

Cylinders

Cylinders for shipping liquid chlorine by express, less carload, or box carload freight, are of various sizes ranging from 10 pounds net to 150 pounds net.

WEIGHTS OF 100 AND 150-LB. CYLINDERS

Net Contents	100 pounds	150 pounds
Average Tare Weight	93 pounds	123 pounds
Average Gross Weight	193 pounds	273 pounds

Minimum carloads comprise one hundred and fifty 100-pound cylinders or one hundred and eleven 150-pound cylinders.

Figure 6 illustrates the standard chlorine cylinder valve designed by the Chlorine Institute and now used by nearly all chlorine shippers. The stem "A" is of Monel metal and one complete turn in a counter-clockwise direction opens the valve so as to permit the maximum discharge of gas. A "frozen"

*From a bulletin on "Liquid Chlorine," prepared and distributed by Pennsylvania Salt Mfg. Co., March, 1936.

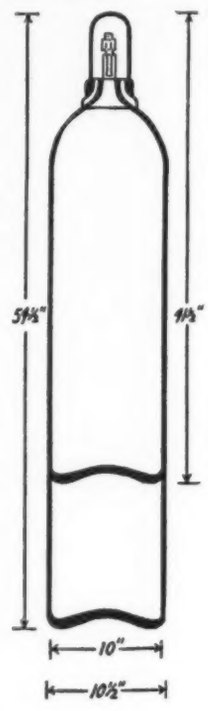
stem can usually be freed by slightly loosening the packing nut "C," tapping the top of the stem lightly, and then giving the valve wrench a sharp rap with the palm of the hand. The body "B" is a bronze and all connections to it are tightened by turning in a clockwise direction. Gas leaks around the stem can be checked by tightening the packing nut. *Under no circumstances tamper with safety plug "D."* It is below the valve seat and, therefore, cannot be controlled by the valve. Fusible metal in this plug softens at temperatures exceeding 157° F., hence cylinders should never be exposed to such temperatures for even short durations.

The valve outlet threads are standard ¾-inch hose coupling to which an auxiliary valve (containing a fiber or lead gasket) may be connected. However, these threads are bronze and are easily damaged. The clamp and adaptor shown in Figure 7 is the more practical type of connection.

Handling Cylinders

The handling of cylinders requires no expensive equipment. It is preferable that they be transported and stored in an upright position. Light, rubber-tired, two-wheeled trucks are convenient for moving them on level floors. Where cylinders have to be lifted above the ground floor a crane, or hoist, equipped with a special cradle, or carrier, should be provided in the absence of an elevator.

The maximum discharge rate of chlorine gas at 70° F. is approximately 35 pounds per 24 hours for a 100- and 150-pound cylinder. This rate may be increased by improving the circulation of air around the cylinder, or by raising the temperature. Under no circumstances should the application of heat be made directly to the fusible plug. The practical method of heating cylinders is by means of a thermostatically controlled water bath in which the temperature is limited to 100° F. Even this procedure is questionable if used in conjunction with a chlorinator because uneven temperatures prevail which in turn cause condensation difficulties. Where chlorine is used in equipment operating under cylinder pressures, it is essential that the cylinder temperature be no higher than that of the gas lines or chlorinator. Otherwise condensation will certainly occur with attending operating irregularities. (See Fig. 9.)



Cross Section of 100- and 150-Pound Cylinders

Fig. 5—Various Sizes of Cylinders

As soon as the cylinder is emptied, suction is set up tending to draw water and foreign matter back into the cylinder. This has caused several cylinder failures which could have been avoided by closing the cylinder valve as soon as the cylinder is empty.

Multiple Unit Tank Cars—Ton Containers

The multiple unit tank car is adapted for large chlorine consumers who desire a more flexible unit than the standard chlorine tank car. It consists of an underframe carrying 15 one-ton drums. Classed as a tank car, the underframe and units are subject to free freight movement both ways, freight being assessed only on the net contents of the car.

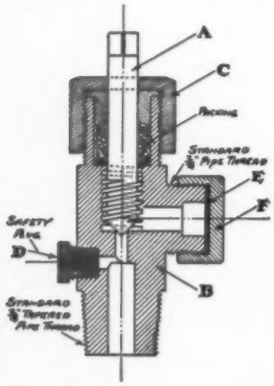


Fig. 6—Cross Section of Standard Cylinder Valve

Each of the unit containers holds 2000 pounds of chlorine. *This shipping container is authorized by the Interstate Commerce Commission for common carrier movement only as an integral part of a fifteen unit car. Multiple unit and tank cars may be consigned only to private sidings, or to approved public sidings.* (*Par.* 431*B I. C. C., Regulations as amended* 1933.) Where unloading conditions are ideal it is a useful package of chlorine because its units are of such size as to permit reasonable movability yet not requiring the frequent changing necessary when using small cylinders.

Each container is equipped with 2 valves, 2 internal eduction pipes, 3 fusible (157° F.) safety plugs in each end, and a removable valve hood. The valves are identical with the standard cylinder valves, except they are provided with larger internal valve openings and are not fitted with safety plugs.

Multiple unit tank cars are not recommended for plants using less than 200 pounds of chlorine per day.

Handling Ton Containers

Due to the size and weight of ton containers, special equipment is required for unloading and transporting to storage or service rooms. Stationary or movable cranes, travelling overhead rail hoists, trucks, and dollies have been employed to meet the peculiar needs of individual plants. Some type of lifting rig is necessary for use with cranes or hoists.

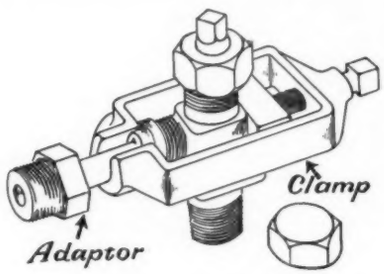


Fig. 7—Clamp and Adapter

Containers are more easily handled and serviced from a prone position. Before servicing the container should be rolled or adjusted so one valve is directly above the other as shown in Figure 12. In this position, liquid chlorine may be discharged from the bottom valve and gaseous chlorine from the top valve. Some plants concerned only with the application of gaseous chlorine prefer to up-end the containers for storing and servicing, which procedure produces material saving in floor space.

The clamp and adaptor connection previously illustrated is recommended as the most practical and flexible connection for container valves. Wrenches for operating these valves should never be longer than seven inches.

Four hundred and twenty pounds per 24 hours is approximately the maximum rate of gas withdrawal for a ton-container at 70° F., operating against 35 pounds per square inch back pressure. This rate may be increased by improving the air circulation around the container, or by raising the room temperature. *Ton containers should never be subjected to the direct application of heat because of the danger of melting the fusible plugs.*

Single Unit Tank Cars

Single unit chlorine tank cars are of two sizes, holding approximately 32,000 and 60,000 pounds of chlorine each. Located in the dome are two liquid withdrawal valves on the longitudinal axis, two gas valves on the transverse axis, and a safety valve. Each liquid eduction pipe is fitted with a vertically acting ball check which stops the flow of liquid chlorine from the car in case of unloading line breakage, sudden opening of valve, or very heavy withdrawal rates.

The withdrawal of gaseous chlorine from any liquid chlorine container causes refrigeration and subsequent pressure reduction in the container. This effect is markedly increased by the cork insulation on single unit tank cars, and consumers purchasing their chlorine requirements in single unit tank cars may find it necessary to use liquid chlorine vaporizers on their operation requiring chlorine gas. Vaporizers usually employ hot water or steam as their heat sources, and may be equipped with either open or closed jackets.

Piping and Fixtures

A copper tubing built for 500 pounds per square inch working pressure is the preferred material for connecting all chlorine containers to permanent pipe lines.

Dry Chlorine

Black iron pipe is recommended as the preferable material for dry gaseous or liquid chlorine, although steel, copper, or other metal piping which will resist high pressures may be used. While standard weight pipe is satisfactory for all normal chlo-

THE MATHIESON ALKALI WORKS (INC.)

60 East 42nd Street, New York, N. Y.

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MATHIESON LIQUID CHLORINE

Waterworks operators have been specifying "Mathieson" since the pioneer days of shipping liquid chlorine. Increasing quantities are also being used for sewage chlorination throughout the country. For sterilization of swimming pools, Mathieson Chlorine assures safety through trouble-free operation.

Modern container equipment, regularly inspected and conditioned, safeguards the original purity of Mathieson Chlorine. Every container is checked and rechecked to safeguard the purity of the product and insure all equipment arriving in perfect order. All valves, threads and other container parts must be clean, accurately placed and in efficient working condition. Convenient warehouse stocks of Mathieson Chlorine make it immediately available.

Mathieson Liquid Chlorine for water works use is shipped in a special group of aluminum-painted standard steel cylinders of 105 and 150 pounds net. In addition to standard cylinders, multi-unit tank cars carrying 15 one-ton container units have become increasingly popular among large municipal consumers.

Handling Chlorine Safely

To assure safety and efficiency in the handling of chlorine containers, Mathieson offers free of charge to chlorine consumers an attractive wall chart containing information that will eliminate needless hazards and remove unfounded fears. We shall be glad to supply you with one or more of these wall charts to post in appropriate locations.

MATHIESON ANHYDROUS AMMONIA

To water works, swimming pools, etc., using the ammonia-chlorine treatment, Mathieson's unique position as a producer of *both* liquid chlorine and anhydrous ammonia is particularly advantageous. Ordering is more convenient—receipt of shipments and return of containers is simplified. Technical assistance comes to you from those competent to discuss both products.

Meeting the highest published specifications for purity, Mathieson Anhydrous Ammonia is shipped in container equipment which receives the same careful servicing and checking, accorded to that for Mathieson Liquid Chlorine. Mathieson Ammonia is available in 50-lb., 100-lb., and 150-lb. cylinders from 46 warehouse stocks throughout the country and at eight convenient base points.

H T H
True Calcium Hypochlorite

While liquid chlorine will no doubt continue to be the chief source of supply for large scale chlorination operations, H T H solves many a treating problem where difficulties of transportation and application make liquid chlorine either impractical or uneconomic. Simple equipment for proportioning feed of hypochlorite solutions made from H T H has widened the range of usefulness for this product for continuous chlorination of smaller water supplies. Moreover, at both large and small water works, H T H meets the requirements of a reliable emergency or stand-by source of chlorine as no other material is capable of doing.

H T H is a true calcium hypochlorite ($Ca(OCl)_2$) containing over 70% available chlorine. It is a dry, free-flowing powder which dissolves quickly in water. Extremely stable, H T H keeps its strength even after months of storage at summer temperatures.

The 3¼-lb. cans of H T H, packed 12 to the case, are particularly convenient for hypo-chlorination of pipe lines, isolated water supplies and at locations where transportation of the chlorine carrier is a troublesome factor. For continuous or emergency hypo-chlorination of water supplies, the 75-lb. drum is an economical package.

Hypo-Chlorination of Water

"Hypo-Chlorination of Water," a 72-page handbook by Walter L. Savell, contains a complete discussion of such water treatment problems as: Combating algae and slime growths; conditioning filters, sterilizing filter sand; disinfecting new reservoirs, basins, tanks; sterilizing water mains; feeding hypochlorite—selection of equipment; insuring safety in emergencies. We shall be glad to send you a copy of this handbook free of charge.

OTHER MATHIESON CHEMICALS

Light Soda Ash—58%. Shipped in 100-, 150-, 200-, and 300-lb. bags; 300-lb. barrels, and in bulk.

Caustic Soda—76%. Solid caustic shipped in 730-, and 700-lb. drums. Flake caustic shipped in 50-, 100-, and 400-lb. drums.

PH-Plus (Fused Alkali). A special moisture-free alkali for water treatment, fused at 2,200° C. and cast in ½-lb. conical cakes. The cakes have a purity and rate of solution particularly desirable for pH control of swimming pool water and general industrial water treatment. In drums of 115 lbs. net, and in barrels of 200 lbs. net.

Bleaching Powder. Available chlorine content—35-37%. Shipped in special galvanized steel drums of 300 and 800 lbs. average net weight.

C C H (Industrial Hypochlorite). Water works consumers planning to use substantial quantities of hypochlorite for water or sewage treatment are invited to consult with the Mathieson technical staff concerning the possible use of C C H, an industrial hypochlorite containing over 70% available chlorine.

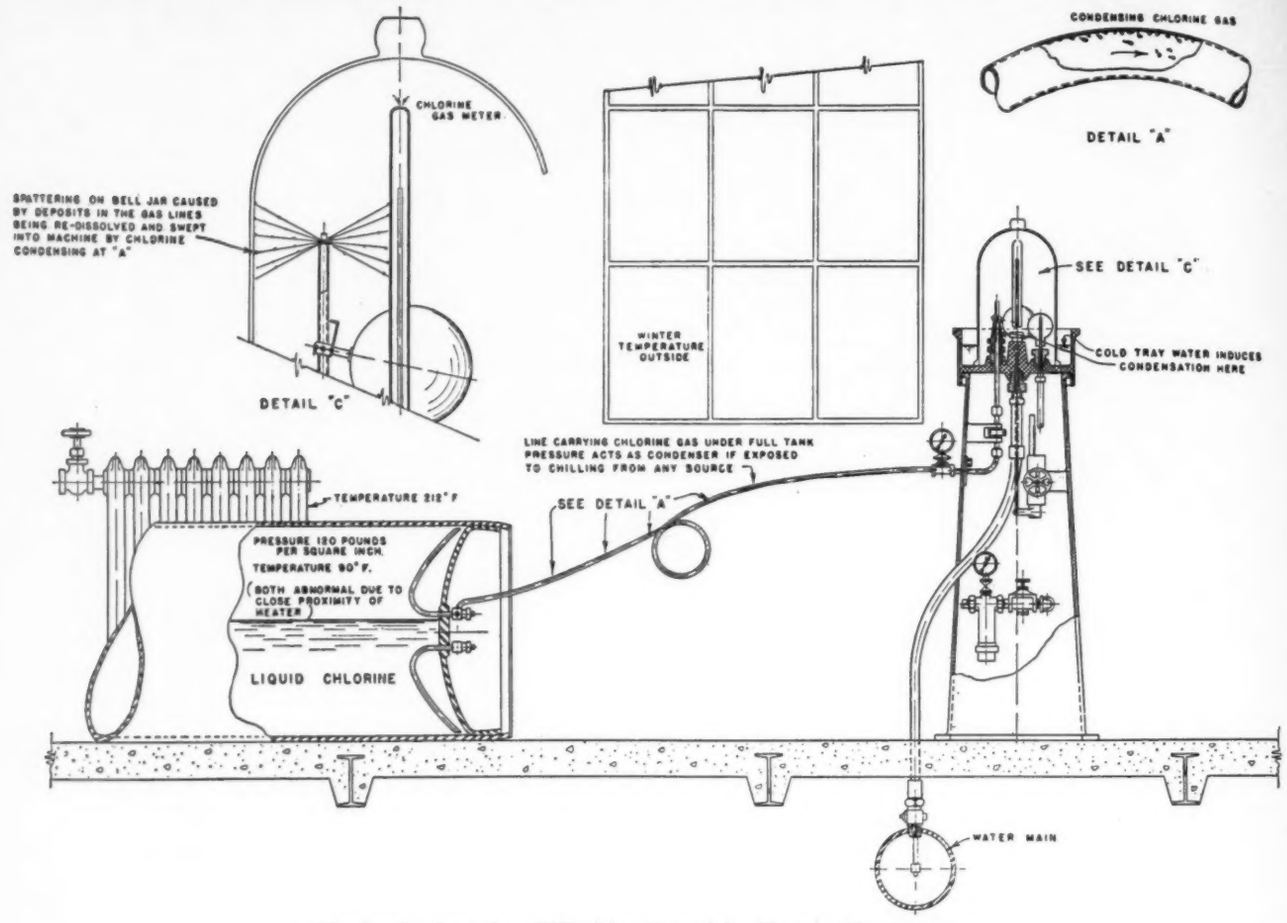

CONDENSING CHLORINE GAS
DETAIL "A"
CHLORINE GAS METER
SPATTERING ON BELL JAR CAUSED BY DEPOSITS IN THE GAS LINES BEING RE-DISSOLVED AND SWEPT INTO MACHINE BY CHLORINE CONDENSING AT "A"
DETAIL "C"
WINTER TEMPERATURE OUTSIDE
SEE DETAIL "C"
COLD TRAY WATER INDUCES CONDENSATION HERE
LINE CARRYING CHLORINE GAS UNDER FULL TANK PRESSURE ACTS AS CONDENSER IF EXPOSED TO CHILLING FROM ANY SOURCE
SEE DETAIL "A"
TEMPERATURE 212° F
PRESSURE 120 POUNDS PER SQUARE INCH.
TEMPERATURE 90° F.
(BOTH ABNORMAL DUE TO CLOSE PROXIMITY OF HEATER)
LIQUID CHLORINE
WATER MAIN

Fig. 9—Condensation Difficulties Caused by Uneven Temperatures

rine pressures, the extra heavy variety is recommended as safer and more practical since abnormal temperatures caused by fires, mechanical strains due to displacements, and corrosion produced by the entrance of moisture are all factors which should be considered. Liquid chlorine lines should be as free from bends and obstructions as possible. Where maximum discharge rates or lifts are required, pipe friction losses should be reduced by using lines of ¾ inch or more in diameter.

Hard rubber pipe is satisfactory for chlorine gas, but should never be used for conveying liquid chlorine. Pressure should not exceed 50 pounds and 80 pounds for the standard and extra heavy hard rubber pipe respectively. *Lines conveying gaseous chlorine should be run on a continuous upgrade in order that condensed (re-liquefied) chlorine will run back into the container.* Where this is impractical, drip legs should be provided in the low points of the pipe line. These legs should terminate in pockets which will assure evaporation of the liquid chlorine. *Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary.*

Pipe joints may be made with standard couplings, unions, or flanges. Standard ammonia flanges are preferable, since their use permits easy inspection and repair to lines. Gaskets should be of lead or asbestos composition. Only special valves for chlorine service should be employed. Usually, the body is of steel or special bronze, and the stem is of Monel metal. Graphite coated asbestos and rubber covered asbestos are recommended for packing. Flanged valves are preferable. Gauges should be of the diaphragm type for chlorine service. *Equipment and lines carrying dry chlorine should not be exposed to excessive heat.*

Wet Chlorine

Wet chlorine is very corrosive to all of the common metals. Materials contacting it must be of earthenware, glass, rubber, one of the special alloys, or noble metals. The handling of wet chlorine is an individual plant problem and specific recommendations can be made only after a survey and study of the various factors involved.

Handling Chlorine Leaks

(The safety information in the following paragraphs has been taken largely from Sale Practices Pamphlet No. 71 of the National Safety Council, as recommended for revision by The Chlorine Institute in December, 1935. For more complete safety information write the National Safety Council, 20 North Wacker Drive, Chicago, Illinois.)

The ventilation provided for the chlorine room, mechanical or otherwise, should be of such nature as to remove and dissipate the gas with the least injury to persons and property.

Stand leaking container upright if possible. This will prevent the escape of liquid chlorine and under these conditions vaporization diminishes rapidly as natural chilling takes place and the escape of chlorine into the air will then be very slow. Ton containers have two valves, and in case of a leaky valve, the container should be rolled so the valves are in vertical plane with the leaky valve upward. In this position the valve will leak chlorine gas, not liquid chlorine.

In case of accident indoors, every effort should be made to remove the leaky container outside the building. *Water played on a gas tank will not stop the leak.* Water in large quantities played on a cylinder gas leak will assist in diluting and dissipating the gas. Water played on a liquid leak may provide

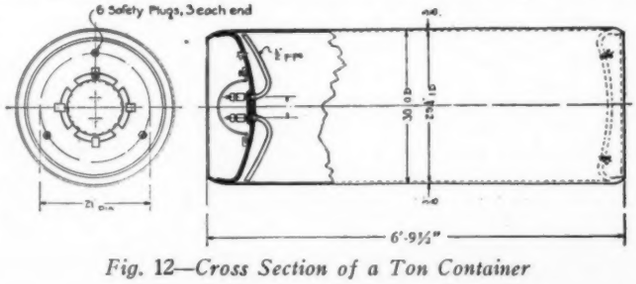


Fig. 12—Cross Section of a Ton Container

PENNSYLVANIA SALT MANUFACTURING CO.

EST. 1850

Widener Building, Philadelphia, Penna.

Offices: New York Chicago St. Louis Pittsburgh Tacoma Wyandotte

PENNSYLVANIA SALT *Chemicals*

TRADE MARK

CHLORINE

The Liquid Chlorine supplied by Pennsylvania Salt Manufacturing Company is uncommonly pure. It contains no "taffy" or other substances to cause chlorinator irregularities. That is one reason why the Chlorine made by this Company has won the complete confidence of water works engineers and municipalities in all parts of the country.

PERCHLORON

An auxiliary hypochlorite installation with an ample supply of Perchloron is a sure safeguard against trouble in emergencies such as floods, fires, and similar occurrences beyond human control. With its available chlorine content of more than 70% and its excellent "keeping" properties, Perchloron is invaluable standby protection. Packed 12 handy-sized cans to the case—no return containers to bother with.

A new 36-page booklet has been prepared covering the uses of Perchloron for Swimming Pool Sanitation, Water Purification, and Sewage Treatment. There are data on preparing Perchloron solutions, emergency feeding, determination of residual chlorine, and other useful facts. Write for this booklet today—it is free.

chlorine hydrate from which the evaporation of gas is slow. These operations should only be undertaken by a competent person wearing an approved gas mask in good order. When a pond or large body of water is nearby, the leaking container should be submerged in the water. Loose earth, cement, lime (both slaked and unslaked), and heavy textiles (both wet and dry), such as bagging and felt, will act as an absorbent or blanket.

It is illegal to ship a defective or leaking chlorine container. If there is an accident, telephone the car owner or nearest chlorine plant for assistance. The telephone numbers and residence addresses of the nearest chlorine plant organization members should be posted in the office of the person in charge of the handling of chlorine in the plant of the user, and in the office of the manager.

Gas Masks

It is imperative that some form of protection be provided for emergencies. Several types of gas masks approved by the U. S. Bureau of Mines and suitable for high concentrations of chlorine are available. For this purpose, a sufficient number of suitable gas masks should be on hand and located at a readily accessible point outside the area likely to be affected in case of accident. The instructions accompanying a mask concerning its care and use should be obeyed implicitly. Everyone who is in danger of being accidentally exposed to high concentrations of chlorine should be provided with a gas mask, preferably to be used by no one else. He should be familiar with the instructions accompanying it and trained to hold his breath and to put the mask on quickly and properly. Periodic strict inspection and maintenance of approved gas masks are essential.

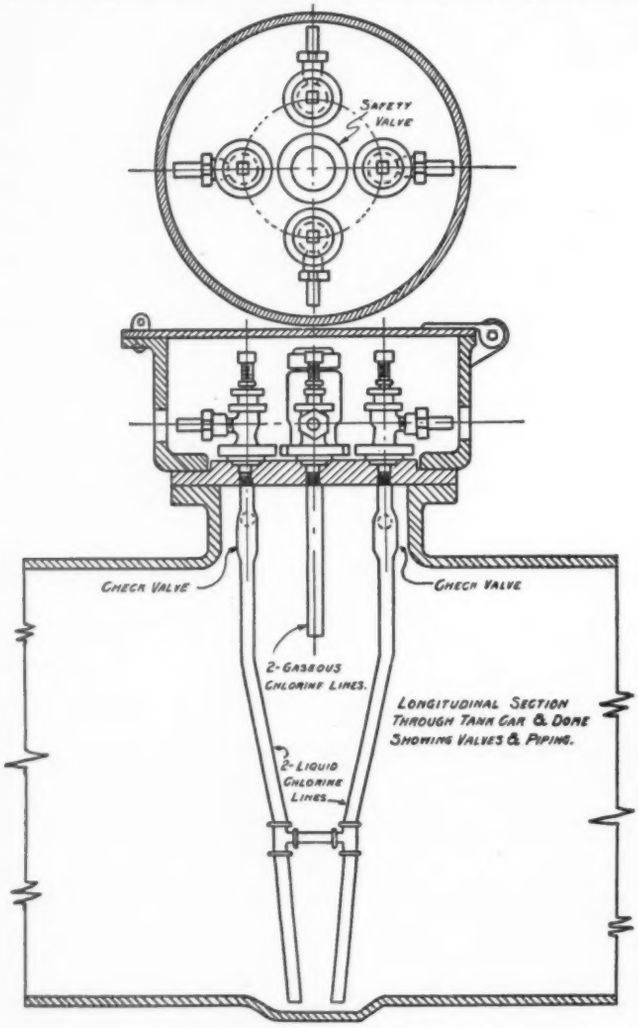
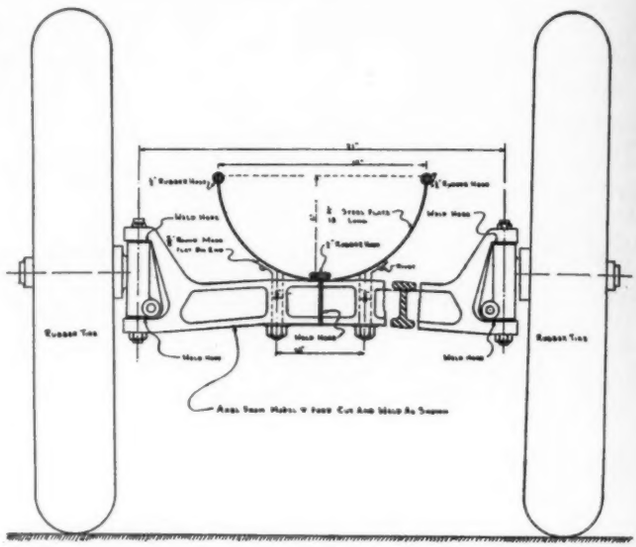


Fig. 17—Details of Dome and Inner Shell of Single Unit Chlorine Tank Car

Safety Cylinder Handling Carriage

The accompanying pictures and detail sketch illustrate a novel, efficient and inexpensive carriage for transport of cylinders containing chlorine, ammonia or other compressed gases.

The device was designed and constructed from the wheels and front axle of what was once a Model "T" Ford automobile. Its ease of handling is self evident and its use saves many a "weak back" and avoids dangers of injury to the "strong men" around water and sewage plants.

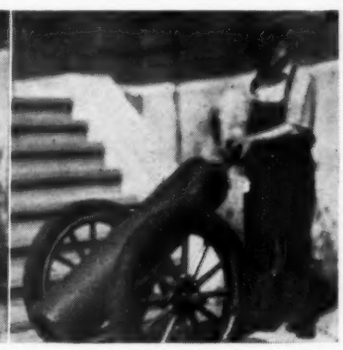


Model "T" Cylinder Carriage

Unique Carriage Designed for Cylinder Handling at the Water Purification Plant of the Philadelphia Suburban Water Co.

To Edward J. Jenkins of the Philadelphia Suburban Water Company, Bryn Mawr, Pa., we are indebted for the illustrations of this unique cylinder truck which was developed in the above plant under his supervision.

In Position



Ready to Ride

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
Dry Chemical Feed Devices, etc.

NEWARK, NEW JERSEY

"The Only Safe Water Is a Sterilized Water"

Boston	Chicago	Detroit	Lexington	Omaha	Seattle
Bridgeport	Cleveland	Indianapolis	Los Angeles	Philadelphia	St. Louis
Buffalo	Columbus	Jacksonville	Madison	Pittsburgh	Syracuse
Charlotte	Dallas	Kansas City	Minneapolis	Roanoke	Washington, D. C.
Chattanooga	Denver	Knoxville	Oklahoma City	San Francisco	

WALLACE & TIERNAN, Ltd., Toronto, Canada — **WALLACE & TIERNAN, Ltd., Montreal, Canada**

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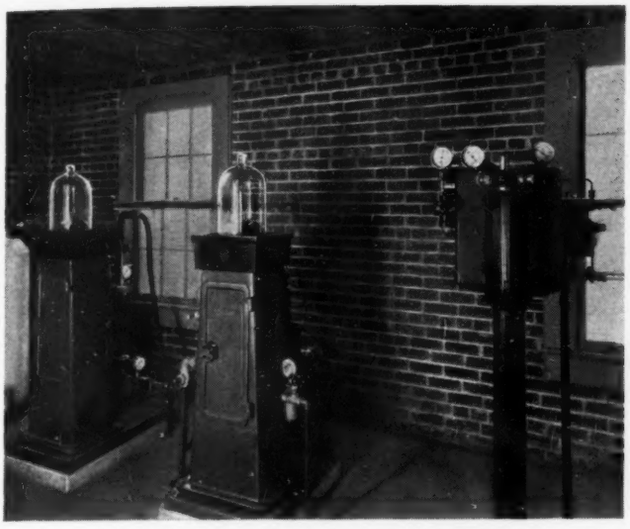


Two Visible Vacuum Chlorinators—1 Manual and 1 Automatic—and Automatic Ammoniator installed at Greenville, S. C.

CHLORINATION

Chlorination is the accepted standard of sterilization in water works practice. Costing only a few cents per million gallons of water treated, easily applied, simply controlled and positive in bactericidal action, it has contributed more than any one other measure in reducing America's typhoid death rate from 30 per 100,000 to less than 3. Whether the source of supply is polluted surface water or clear, sparkling well or spring, its purity should be insured by the certain protection chlorination provides. Over 20,000 units of Wallace & Tiernan equipment in all parts of the world attest the universal accord with which chlorination and W&T Chlorinators are accepted.

Visible Vacuum Control in low capacity equipments —Duplicate "Equiscale" Chlorinators at New London, Conn.

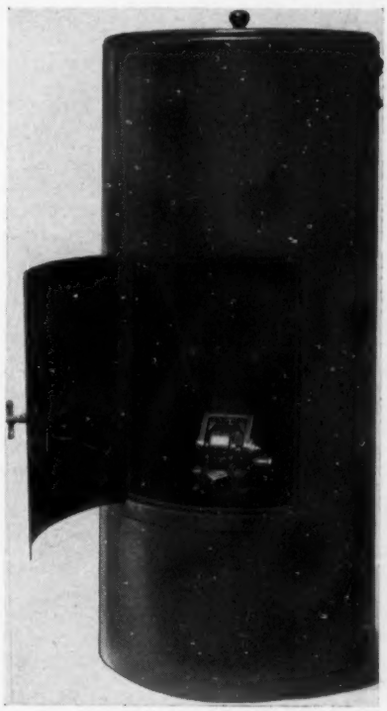
AMMONIATION

The ammonia-chlorine process of water treatment has passed beyond the experimental stage and is accepted as a definite and valued aid in water works operation. Chloramine—formed by the combination of chlorine and ammonia—while somewhat slower in bactericidal action than chlorine, offers many distinct advantages. Chloramine residuals persist over long periods and are tasteless and odorless. Chlorophenol and certain organic tastes and odors are prevented.

Chlorinous tastes are eliminated, this being of particular advantage on small gravity water supplies with widely fluctuating flows and with a chlorinator operating at a fixed rate at considerable distance from the town. Aftergrowths in the distribution system are destroyed and algae control made far more efficient owing to the persistent residual being carried through basins, filters and reservoirs. Finally, and most important, a new factor of safety is added by maintaining sterilizing action throughout the distribution system to the consumer's tap, thus eliminating all dangers of subsequent pollution.

APPLICATION OF DRY CHEMICALS

The development of dry chemical application has been of great value in both sanitary and industrial fields. Difficulties from leaking tanks, corroded constant level boxes, clogged orifices, broken valves, and all the untidiness and disagreeable features incident to solution feed systems are eliminated. Of particular advantage in filter plants for applying alum, lime, soda ash or carbon, dry chemical application effects large savings in labor and materials.



Type MOF Dry Chemical Feeder for accurate control of Alum, Lime or Activated Carbon.

W&T EQUIPMENT

Complete in both arrangement and capacity, the W&T line of Chlorinators, Ammoniators and Dry Chemical Feeders is designed to meet every water works requirement. Long life, low maintenance and utmost accuracy and dependability characterize each installation, reinforced by the services of a nationwide organization operating from 29 Sales and Service Headquarters. The recommendation of W&T field representatives involve no obligation. Feel free to call on them.

Current literature on the many phases of chlorination, ammoniation and dry chemical feed is available on request.

SOME PRACTICAL ASPECTS OF HANDLING CHLORINE

By CHRIS F. BINGHAM*

Barberton, O.

There appeared in the September, 1935, issue of the Journal of the American Water Works Association a valuable report, dealing with chlorine, by the Committee on Chemical Hazards in Water Works. This paper is intended to record various practical experiences in chlorine handling and opinions that in their nature had no place in the above committee report. However, the writer will quote freely from the report, where deemed advisable, and recommends that those interested procure a copy of the journal containing it.

Properties of Chlorine

Chlorine gas is approximately two and one-half times as heavy as air at normal temperature and pressure, and hence, leaking chlorine, tends to settle and collect in low places and on the floor of an enclosed room.

Chlorine is neither flammable or explosive. The dry gas does not attack iron, copper, or lead at ordinary room temperature. However, in the presence of moisture it is very corrosive and combines readily with most metals except those classed as the "noble" metals and special alloys. It is important to note that even the dry gas becomes very corrosive at temperatures above 300 degrees F. and is likely to become so at temperatures as low as 195 deg. F.

Chlorine Lines

Rubber and the noble metals are sufficiently resistant to the action of wet chlorine to be satisfactory materials to handle either the moist gas or water solutions. Liquid chlorine in itself cannot, however, be used with hard rubber. During the last year and a half plant tests have been made in Richmond to determine the resistance of asbestos-cement pipe to chlorine solutions. As a result, the prechlorination and copperas-chlorine solution systems have been rebuilt using two and one-half inch "Transite" Class "B" pipe and Class "S" elbows. So far, this installation has given excellent service, the only difficulty encountered was due to its brittleness and the lack of sufficient mechanical support—a few sections of the pipe being broken by strains before adequately supported. The chlorine solution seems to "wet" the inside of the pipe to a depth of ⅛ to 3/16-inch and then stop, no further change was noted in the experimental installation or in the new permanent installation after two months of heavy use.

Extra heavy iron pipe with wrought iron fittings and litharged joints should be used for the chlorine pressure lines. Litharge that has been opened for some time seems to form a carbonate coating on the particles which result in a never-hardening and oily joint compound which will allow the joint to leak probably. Only new litharge is recommended. Care taken in the correct installation of pressure feed lines is a thousand fold repaid. Ammonia valves (of steel) have been used in the chlorine pressure lines at Richmond with satisfactory results, but where possible the standard Chlorine Institute ton container valve has been used because of its convenience, economy and superior construction. In general chlorine needle valves should have either Hastelloy "C" or Monel Metal stems, and joint valve bodies may be constructed of steel, brass or Hastelloy "C."

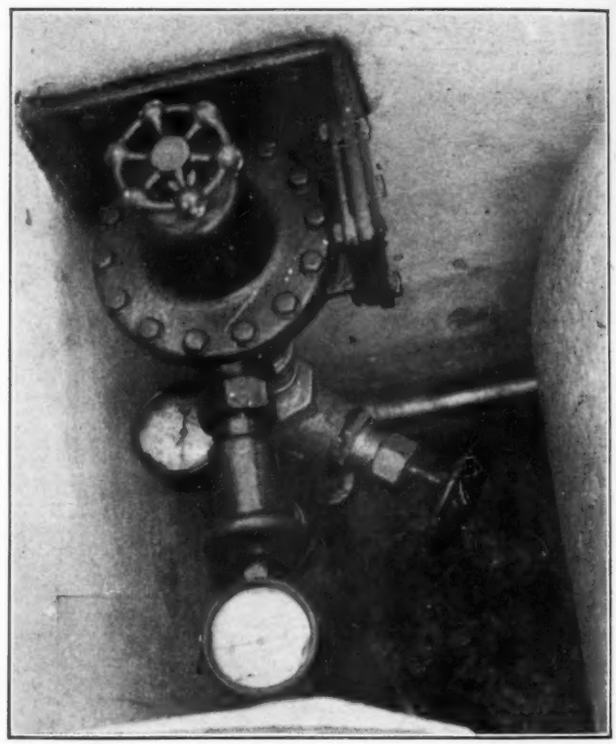
Soft copper tubing connections (cadmium plated) are used in connecting the one-ton chlorine containers to the piping system. We specify that a small wrench "hold" be milled on the bushing on the tubing, to allow holding the tube at the joint during tightening of the coupling. This, to prevent wringing off the tube at that point. The tubing becomes quite hard and rigid after continued service, but its ductility may be renewed by heating slowly to a dull red heat and quenching in water—the customary method of copper softening.

Hard drawn copper fittings and pipe of the "Streamline" type also have been used with essentially *pure* silver as the solder instead of the regular solder, furnished for such pipe, which chlorine attacks. A silver coin will serve as satisfactory solder. High copper content brass fittings have been used with this type of pipe also and seem to work entirely satisfactorily.

Avoiding Condensation Troubles

The gas feed lines should, if possible, always be warmer than the chlorine containers to avoid condensation (re-liquifaction of chlorine) and consequent problems. These lines should also be run on a continuous upgrade from the containers in order that the condensed liquid chlorine will flow back to the containers. Such theoretical conditions cannot always exist practically and, in cases where this is impossible, drip-legs should be provided at every low point on the pipe line—especially so near the chlorinators. Blow-off cocks or other bleeding arrangements are not recommended since they are both dangerous and unnecessary. If the drip legs are so located that the room temperature does not keep the condensate vaporizing at a satisfactory rate, additional heat may be applied by warming with a 100-watt electric bulb permanently installed beneath the leg. The size of the leg varies with the conditions, but it is recommended to be 1¼ times as large as the volume of the pipe line leading from the chlorine container to the leg.

Chlorine reacts with grease and oil to form voluminous frothy substances; with gasoline and other petroleum distillates to form solid complex chlorinated hydro-carbons. Alcohol and ether, even in traces, are converted to solid waxy hexachloroethane. It

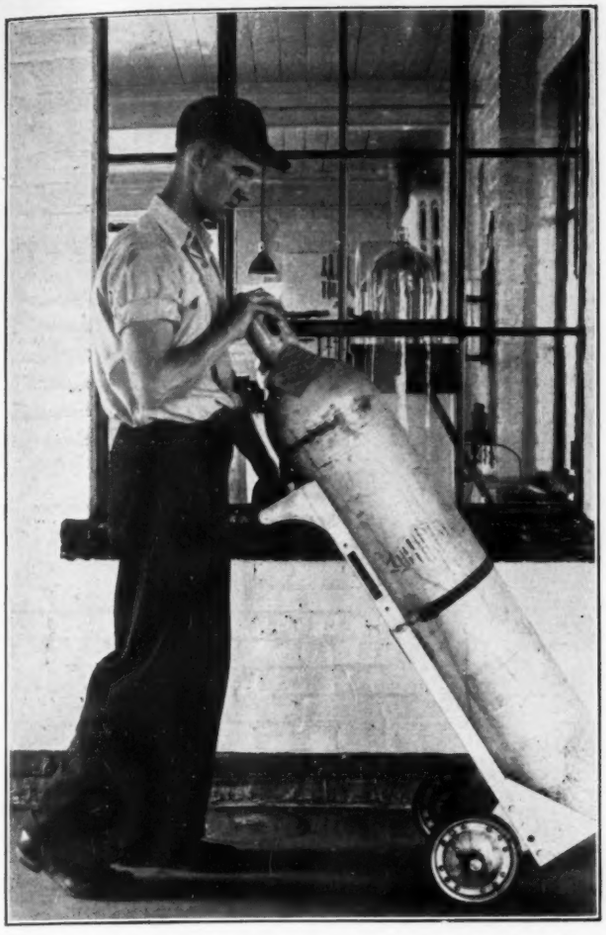


One of the Reducing Valves (Looking Down) on the Chlorine Feed Lines. It Is Located on the Manifold Just Beyond the Containers in the Outside Gassing Chamber

is important, therefore, that all grease, moisture, etc., should be thoroughly removed from chlorine lines during their erection. Methane derivatives, chloroform, wood alcohol, and carbon-tetrachloride are the only safe chlorine equipment cleansers to employ.

Whereas, drip legs are very helpful, condensation in chlorine lines should be avoided. If the gas leaving the container drops only a few degrees in temperature it will condense into a liquid in the feed lines and find its way into the chlorinators, with its consequent troubles. This condition can best be avoided by reducing the pressure at the containers to the lowest point permissible for the proper operation of the machines. In fact, if

*Plant Supt., Div. of Filtration, Dept. Public Utilities, Richmond, Va., at time of preparation of this article. Now Tech. Service Engr., Columbia Alkali Corp.



Handy Light Weight Safety Truck for Cylinder Handling (Courtesy Carl Leipold, Winnetka, Ill.)

the line pressure be kept at 40 pounds per square inch or less no condensation can occur in the lines except at extreme cold temperatures. In Richmond, by keeping the reducing valves (in duplicate) set at 35 pounds per square inch, no liquefaction has resulted, although the chlorine feed lines are 400 feet long and the containers are in compartments outside of the plant which get quite warm in summer and also are artificially warmed in cold weather—an ideal condition for condensation in the feed lines.

Chlorine, in distilled water, at 49.2 deg. F. will form chloral-hydrate, commonly referred to as "chlorine ice." This condition is frequently found in the trays of vacuum type chlorinators during cold weather; but may be overcome by placing an electric light under the tray of the chlorinator. At the same time, reducing the water flow through the tray is also helpful. Since the solubility curve is a very sharp one a rise of only one or two degrees of the water is sufficient to do away with the trouble.

Container Temperatures and Pressures

The per cent of container volume occupied by liquid chlorine in the containers, when loaded to the limit permitted by the Interstate Commerce Commission regulations, is such that at 153.9 deg. F. the cylinder becomes completely filled due to the expansion of the liquid chlorine. Liquids do not have the compressibility or cushioning effect possessed by gases hence any further increase in the temperature will cause enormous pressure in the containers. For this reason, fusible plugs are provided which are intended to soften at slightly above this temperature and thus relieve the dangerous pressure. It is important, therefore, to keep the cylinders below this temperature regardless of the amount of chlorine that they may contain. Experience at the Richmond plant justifies this warning.

There are several practical precautions suggested by the above facts. Cylinders should never be directly heated by flame, steam or even electrical means that can exceed 160 deg. F. To avoid such hazard, warm air from the building is blown through an underground pipe to the containers which are housed in compartments outside of the plant. Secondly, a full cold chlorine cylinder has a lower pressure than one at room temperature; hence, if they are connected together as on a header, the cold cylinder will actually draw in chlorine. If the valve is then closed the overloaded cold cylinder may cause trouble when it becomes warm, even to room temperature. Hence, cylinders should be brought to about the same temperature before being connected together. As another example, the re-loading of containers thought to be empty, is absolutely forbidden unless under technical supervision.

If gas is drawn from a container, the pressure within the container will be reduced. If a constant supply of gas at constant pressure is to be maintained, then heat must be applied to the liquid in the container. The more rapidly the gas is removed, the more rapidly heat must enter. This is usually accomplished by increasing the room temperature. If instead of adding heat, the container is cooled—the pressure falls. This is why a leaking cylinder should be cooled as rapidly as possible. Different opinions exist as to the maximum rate that gas may be drawn from cylinders. Experiments at Richmond have indicated that as much as 800 pounds per day may be drawn from the standard one ton container, in the summer when indoors, with pressure maintained on the gas line at not less than 30 pounds per square inch. However, 400 to 450 pounds per day is about the maximum successful continuous rate of supply from these containers. With the 150 pound cylinder the rate is about 30 pounds per day. Increasing the room temperature and providing air circulation will increase the rate of gassing. Especially so with a full cylinder because there is then a large area of the liquid exposed to the sides of the warmed container. Adequate air circulation is a considerable aid in maintaining sustained gassing rates.

Handling Containers

Containers are built of steel and may be safely handled with care. Dropping or bumping containers is extremely dangerous, and facilities used in handling should be carefully arranged to prevent such rough treatment. Hoisting is to be avoided if possible. Low, rubber tired trucks are preferable if conditions allow. A rubber tired light weight hand-truck for 150 pounds cylinders, first used by Carl Liepold at Winnetka, Ill., plant has proven both safe and convenient. The overhead monorail system used in Richmond for ton containers, involves the use of a lifting hook used to reduce space and suitable for low head operation on such a system. Out of doors storage is provided in racks, the enclosed section being the warmed gassing chamber. The maximum chlorine temperature yet found in these stored containers is 108 deg. F. or a pressure of 160 pounds which is amply safe. In warmer climates it may be well to shield stored containers from direct heat of the sun.

Chlorine may be safely stored indoors. Having the containers in operation mounted near the control machine undoubtedly has its advantages. In small installations, having in storage or in use only a few 150 pound cylinders, this risk is not serious and the practice is to be recommended, but when larger quantities of chlorine are necessary the advantage of the out of door storage and gassing chamber, with only the chlorine feed lines and the machines in the building, is certainly evident.

Ventilation Facilities and Leak Handling

When storage and operating containers are indoors adequate and reliable ventilation is essential. Exhaust air ducts draining

The Chlorine Leak Tester

air from the room should intake at the *floor level* and a fan forcing air into the room should drive the chlorine atmosphere directly out of the building. Where steam is available, a suitably designed ejector system, with discharge to a sewer or stack, is perhaps the best disposition of the escaped chlorine.

The use of neutralization tanks containing caustic, or attempting to stop a leak by spraying water on the leak, or cooling with ice and salt, while theoretically correct, are of doubtful practical value. Practically it has been found at the Richmond plant that the best disposal is by submerging the cylinder, as for example, in the raw water flume, or other convenient large body of flowing water. "Dry Ice" (solid carbon dioxide), is the only method used successfully in cooling a cylinder to stop a leak by sufficiently reducing the gas pressure.

A suitable number of gas masks, of a design approved by the U. S. Bureau of Mines, should be readily available in a convenient location, and all employes should be trained in the correct procedure in putting on the masks. There is quite a prejudice among a large number of operators against the use of a mask in stopping small leaks. Contrary to general statements otherwise, that chlorine exposures produce no cumulative effects, the writer has noted cases of men repeatedly exposing themselves to small concentrations and have ended up with irritations such as results from a heavy concentration. It is well to note that the life of a canister type gas mask of the soda lime-activated charcoal type, depends not only upon the extent to which it is put to active service, but upon the storage conditions. Such canisters deteriorate rather rapidly when left open to the air and, therefore, the bottom opening of the canister should be kept sealed with the plug or disc supplied by the manufacturer. The useful life of a canister cannot be predicted and a fresh canister should always be available. Canisters should be replaced periodically, regardless of use.

Remember three simple rules in using a gas mask:

1. Never use where there is any danger of a deficiency of oxygen.
2. The life of the canister is an unknown quantity.
3. Any gas mask job is a *two man* job.

Even small chlorine leaks are dangerous and should be stopped immediately. A chlorine leak may be readily located by means of aqua ammonia. The best procedure so far found in Richmond consists of the use of a "blow-bottle" here illustrated. This is a bottle of suitable size to carry in one hand conveniently. A rubber atomizer bulb is attached and permits the operator to blow ammonia fumes from the bottle while holding the outlet nozzle near the suspected leak. This outfit can be easily manipulated with one hand.

Water played on a gas leak will not stop the leak, but in large quantities will assist in diluting and dissipating the gas. However, water played in a liquid leak will provide chlorine hydrate, from which hydrate the evaporation is slow. Such operations should be undertaken only by a competent person wearing an approved gas mask and such protective clothing as rubber gloves (loose fitting) and a rubber apron.

There is so much difference of opinion (See A.W.W.A. Committee Report, Jour. A.W.W.A., Sept., 1935) as to the best medical treatment to be given those suffering from exposure to chlorine; and the "Do's and Dont's" are almost as numerous; that the writer rafrains from expressing any opinion for anyone else's use on this subject at this time.

Flexibility of Chlorinator Service

Chlorine control machines are relatively expensive, yet ample reserve against extra demands or repairs is absolutely essential in every plant. To reduce the number of machines needed, and yet leave reliable reserve at the Richmond plant has been installed a most successful transfer system. Three points of chlorine application before filtration and four control machines are available on the transfer. By means of the transfer system, the opening of a valve permits any or all of the four chlorinators to supply any or all of the three points of application. By changing hose connections two additional control machines may be substituted thus making six machines almost immediately available at any point of chlorine application. Thus six machines give as reliable service as would ordinarily necessitate nine machines.

The author wishes to gratefully acknowledge his indebtedness for the suggestions and criticisms of: M. C. Smith, Chairman of the A. W. W. A. Committee on Chemical Hazards in Water Works; L. H. Enslow, Research Engineer of the Chlorine Institute, and Editor of WATER WORKS AND SEWERAGE, and to Carl Liepold of Winnetka, Ill.

Experience in Sterilizing New Mains

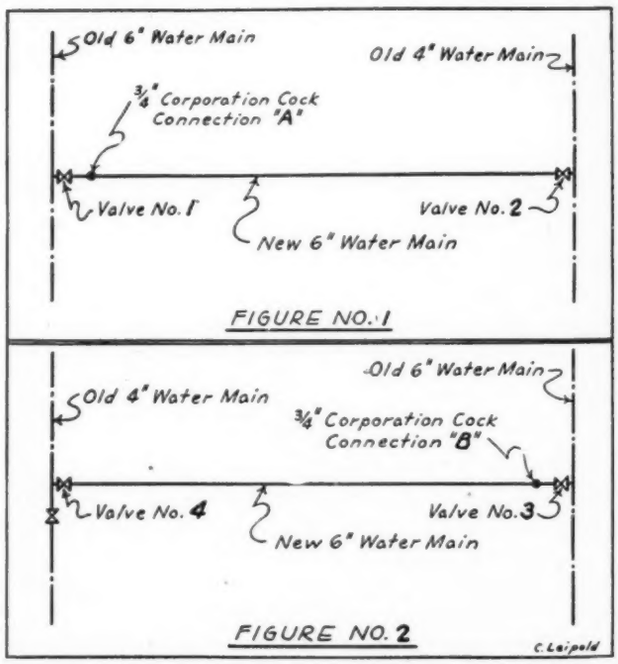
By CARL LEIPOLD

Superintendent of Filtration, Winnetka, Ill.

It was shown by tests made at the time of sterilizing a new pipe line that it is very essential that the water added to the pipe will distribute the applied "H T H" (calcium hypochlorite) uniformly through all parts of the new pipe.

On completion of a new pipe line (Fig. 1) about thirty grams (a heaping handful) of "H T H," representing a treatment of 100 lbs. chlorine per million gallons of water, was applied through a paper funnel placed in the neck of the corporation cock at connection "A" and the pipe was filled with water through valve No. 1. Residual chlorine tests made of the water samples collected from connection "A" after all the air was removed and the pipe was full of water, showed only .10 to .20 p.p.m. of free chlorine. After a chlorine contact period of 3 hours, valve No. 2 was opened and the new pipe line was flushed through connection "A." Residual chlorine tests made of the water samples collected from connection "A" showed a gradual increase of free chlorine and after 30 minutes of flushing the test showed a deep red color. These results indicated that on filling the pipe line, the largest portion of the disinfectant had been carried to the far end of the pipe line near valve No. 2, leaving no chlorine for sterilization at the near end of the pipe line where introduced.

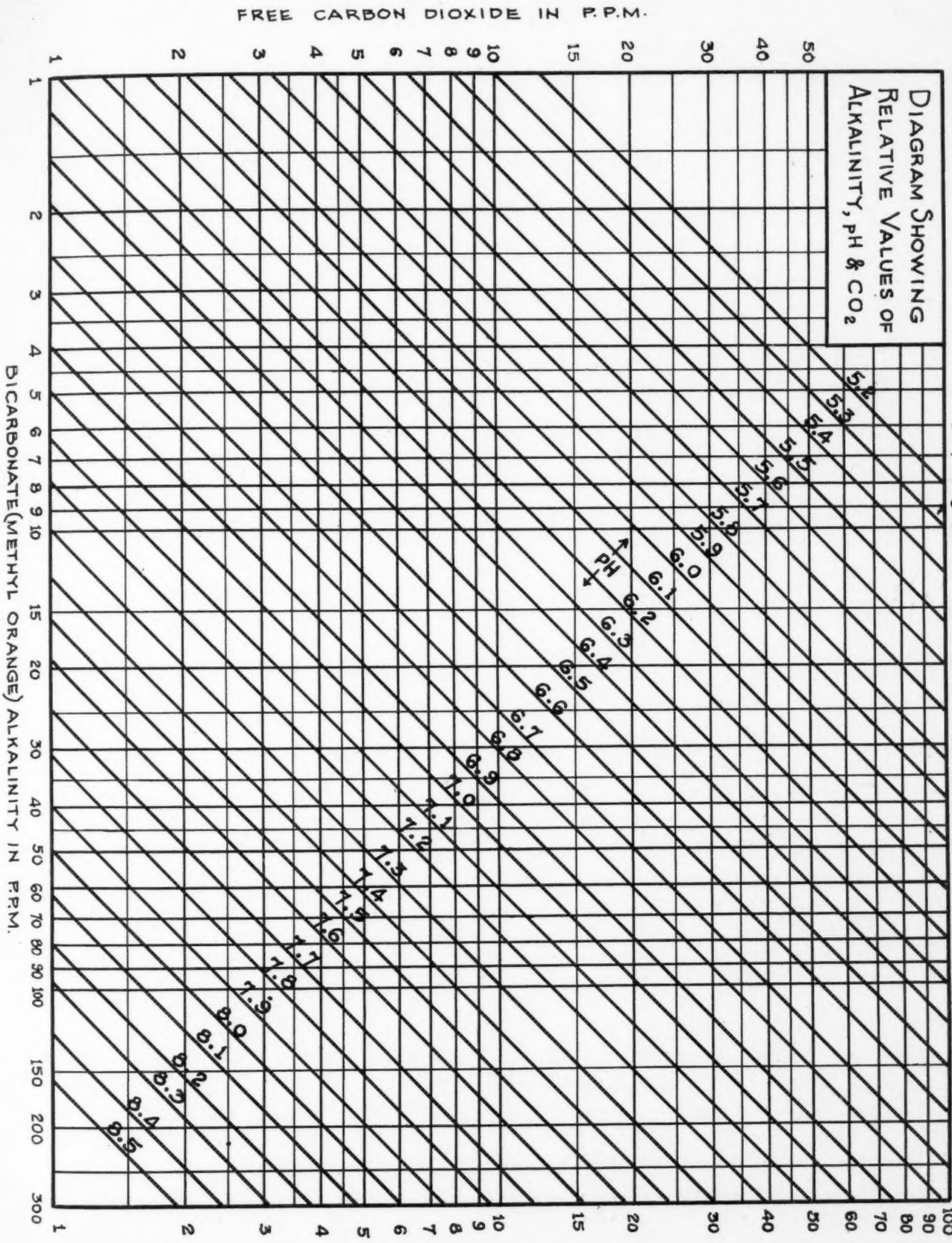
On completion of another new pipe line (Fig. 2) the same sterilizing procedures were carried out as described above with the exception that a different method of filling the pipe line with water was employed. This pipe line was partially filled with water through valve No. 3 and then completely filled with water through valve No. 4. Flushing the pipe line through connection "B" from valve No. 4 was done until the residual chlorine test of the water sample showed a deep red color. It was then closed off. After a chlorine contact period of two hours, valve No. 4 was again opened and the new pipe line was flushed through connection "B." The residual chlorine tests made of the water samples collected from connection "B" showed a gradual decrease of free chlorine and after 30 minutes of flushing the test showed no free chlorine. These results indicated that the "H T H" had been uniformly mixed throughout the pipe line by proper control of the valves.



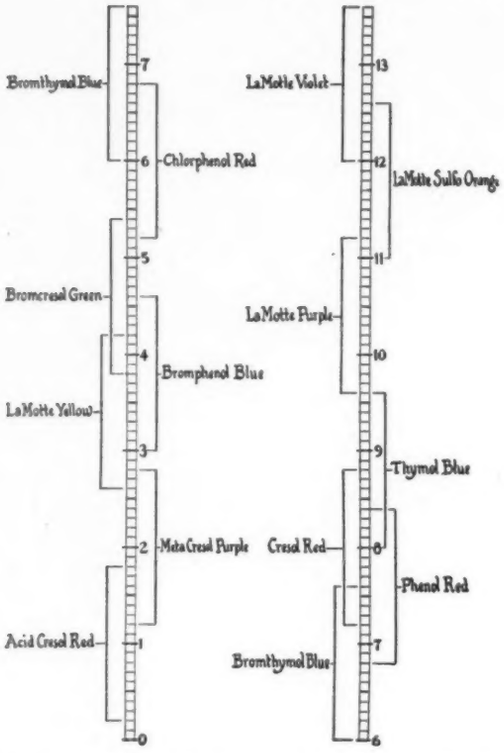
Illustrating an Effective (Fig. 2) and an Ineffective (Fig. 1) Method of Sterilizing Water Mains

Conversion Chart—pH, Alkalinity, Carbon Dioxide

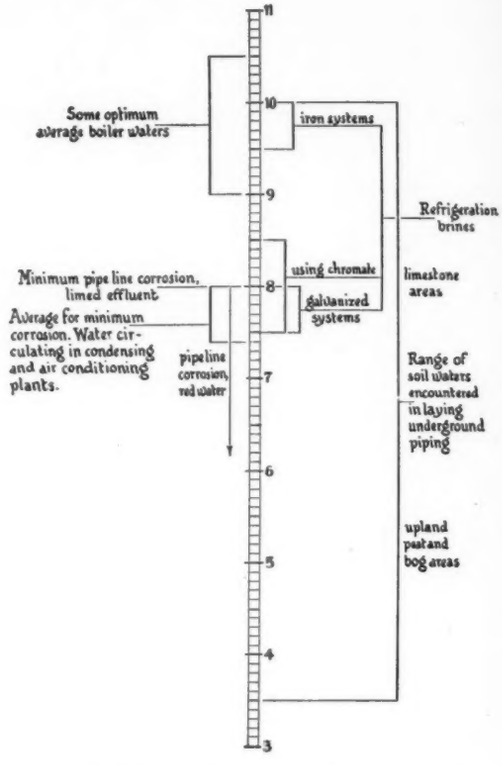
NOTE: *This chart has an especial usefulness in determining free carbon-dioxide content of waters without making the tedious and frequently inaccurate CO_2 titration. Alkalinity and pH readings are more easily and accurately made. To find CO_2 content —Locate pH value diagonal; follow it to intersection with alkalinity value vertical. The horizontal line passing through this same point reveals the correct free CO_2 content. (This chart was supplied by T. M. Riddick, Consulting Chemist, New York City.*



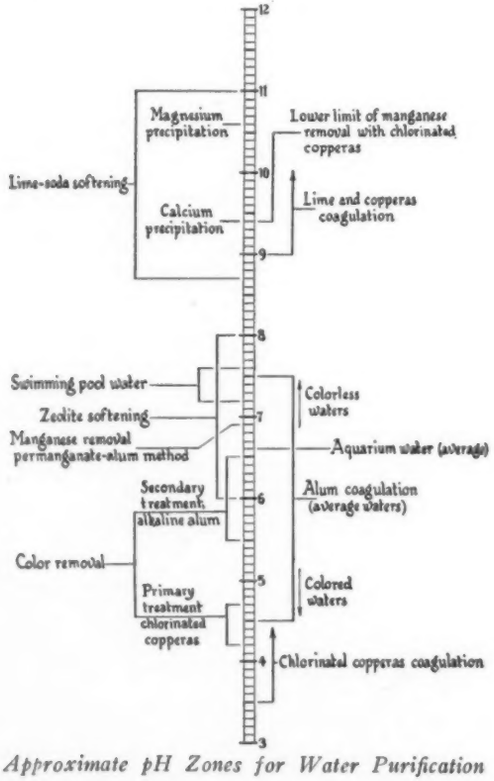
pH ZONES OF IMPORT IN WATER SUPPLY AND SEWAGE TREATMENT PRACTICE *



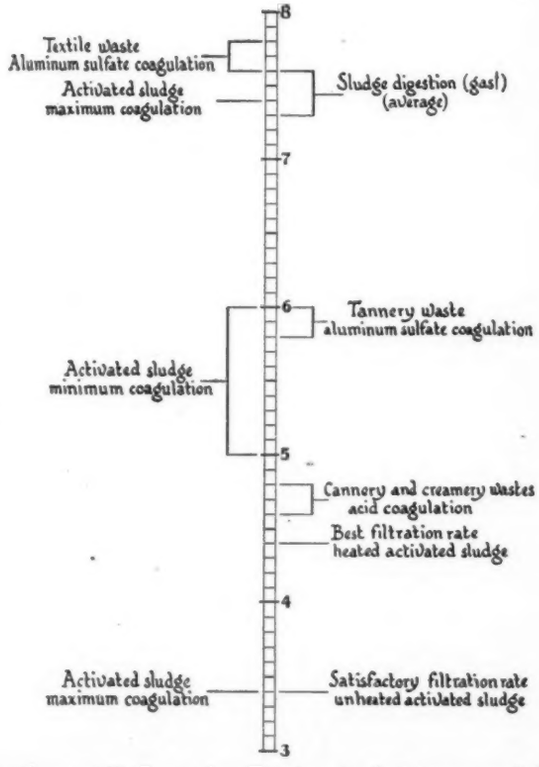
Ranges of Selected Indicators for pH Determination


Some optimum average boiler waters
iron systems
Refrigeration brines
Minimum pipe line corrosion, limed effluent
using chromate
limestone areas
galvanized systems
Average for minimum corrosion. Water circulating in condensing and air conditioning plants.
pipeline corrosion, red water
Range of soil waters encountered in laying underground piping
upland peat and bog areas

Approximate pH Zones Encountered in Common Corrosion Problems



Approximate pH Zones for Water Purification


Textile waste Aluminum sulfate coagulation
Activated sludge maximum coagulation
Sludge digestion (gas!) (average)
Tannery waste aluminum sulfate coagulation
Activated sludge minimum coagulation
Cannery and creamery wastes acid coagulation
Best filtration rate heated activated sludge
Activated sludge maximum coagulation
Satisfactory filtration rate unheated activated sludge

Approximate pH Zones for Treatment of Sewages and Some Industrial Wastes

*Reproduced from the reference work "pH and Its Practical Application"—LaMotte, Kenny & Reed—(Williams and Wilkins, Publishers, Baltimore, Md.)

SEWERAGE

Whereas, this section is devoted almost exclusively to Sewerage, it was not possible to segregate much of the material, which pertains to Water as well as Sewage, except at the expense of duplication.

The Water Works Section will be found to contain considerable material of direct bearing on Sewerage. Such, for example, are "Main Line Metering"; "The Parshall Flume"; "Pumps and Pumping"; Elemination of Check Valve Slam"; Practical Hydraulics"; "Practical Electricity in the Plant"; "Chlorine and its Safe Handling," et. al.

In the rear of this Sewerage Section are Tables, Formulae and Conversion Factors as valuable in water works as in sewerage practices.—Ed.

MAINTAINING A SEWERAGE SYSTEM

By GEORGE E. FINCK

Engineer, Bureau of Sewers, Baltimore, Md.

The extent of maintenance required to keep a sewerage system in successful operation may be traced more or less to the following causes: (1) Poor Design and Construction; (2) Depreciation and Misuse.

The amount of maintenance necessary on account of depreciation due to wear and tear is usually not great, particularly if the system is new, and of good workmanship and material. A frequent source of trouble, however, if not guarded against will result from the tapping of sewers for extension of house connections. No sewer in the City of Baltimore is permitted to be tapped unless a permit from this Bureau has been issued, and the *work must be done under the supervision of a Department Inspector* and by a qualified pipe layer. Noisy and broken manhole covers add a great deal to general maintenance work and numerous inlet heads have to be repaired and replaced from time to time, all of which is the result of increased traffic.

Dealing With the Root Problem

To have low maintenance costs, good construction is essential under careful and competent inspectors. A very important factor in this respect is the making of tight joints for the exclusion of ground water and to guard against the entrance of tree roots. Numerous chokages in the sanitary sewers of Baltimore are due to the roots of poplar and willow trees. The roots of oak and similar shade trees do not seem to give any trouble. In each case where the sewer becomes chocked because of tree roots, and it is necessary to uncover the sewer, the joints through which the roots have passed are made over with great care in the following manner. A ring of jute is inserted in the bell of the pipe the same as when the usual Portland cement joint is made. Then puddle clay, to which has been added a liberal quantity of coarse salt is packed over the jute to within one-half inch of the end of the bell. On top of this is placed a mortar of cement and sand. This type of joint has proved very effective against the entrance of tree roots. The planting of poplar trees on public highways of the city of Baltimore is now prohibited.

The misuse of the sanitary sewerage system is probably the principal contributing factor to high maintenance costs. Although sewers are intended for definite purposes, they often are used as a means of disposing of materials intended for the rubbish pile. The following are but a few of the objects which have been taken from Baltimore sewers from time to time: Bricks, flat irons, dish pans, broom handles, bottles, garden hose and occasionally small dead animals. The only conceivable means by which such objects can be introduced into the sewers is by the unauthorized removal of manhole covers and through sewer cleanouts on the plumbing lines.

The amount of maintenance required for the storm drainage system can be held to a minimum if streets are frequently cleaned and the debris removed before it is washed into the drains, where it usually has to be removed at considerable cost. Present day heavy traffic has brought about the necessity for prompt removal of snow. The practice generally followed is to dispose of it into the storm drainage system. It is usually mixed with debris and after the snow has melted in the drains this debris remains behind and has to be removed. It is essential that only large drains should be used for snow removal and great quantities of water used for flushing purposes.

Solution of the Oil Dumping Problem

A serious problem confronting engineers in charge of sewerage systems relates to the disposal of gasoline and oil from automobile crank cases into the storm drains. Many cities have had serious explosions as the result of this practice. The City of Baltimore has to a great extent overcome the problem by the passing of an ordinance requiring that waste oils, greases, crank case drainings and similar products be stored on the premises in tight steel containers. The material is then collected and disposed of periodically under direct control of City authorities. This arrangement has proved satisfactory because it provides garages and similar establishments with a way of disposing of oils and greases, as the City has previously found it almost impossible to police all garages to enforce an existing ordinance which prohibited the discharge of oil and gasoline into the sewers. [A copy of the Baltimore ordinance, covering oil disposed, can be had by addressing the author.—Editor.]

It has been found that the large storm drains require little if any cleaning as they are usually well flushed at every heavy rain. Inlets require periodic cleaning to remove decomposing material and an occasional dead animal. Disinfectants and deodorants are used at times when odors are detected in the inlets.

The principal source of trouble in a sewerage system is usually confined to the smaller sizes, namely 8 inches and 10 inches in diameter. When the larger sewers need cleaning it is usually due to wastes from industrial plants.

Tools and Equipment

The proper selection of cleaning tools plays an important part in helping to decrease maintenance costs. There are two types of cleaning rods in use in Baltimore. Jumbo rods No. 10 used to clean out storm water drains are of wood, 3 ft. in length and about 2 inches thick. They have strength and are light enough to float on the water while being forced through the drain. Other rods used to clean sanitary sewers are 4 ft. long and are 1⅞x1⅞ inches in cross section. Other tools such as scoops, root cutters, etc., are essential. Flexible steel cables with steel rollers at the end are used to clean house sewers.

Flexible Sewer Rods

A new type of equipment has recently been purchased for removing obstructions in main line sewers. It consists of 3 ft. flexible steel rods which can be coupled together with connectors especially designed for the insertion of a proper tool for twisting purposes. The flexible sectional-rod cable, thus made up, is run through a 1½-in. pipe guide rigidly fastened in a vertical position in a manhole, the lower end of which guide points to and partly enters the pipe of the sewer. This provides a guide for the flexible rod cable on the end of which is a suitable boring tool of the cork screw or auger type. The boring tool and cable is advanced forward in the sewer by hand pressure and by means of a twisting action accomplished by a turning tool inserted in the connector. When the obstruction is reached the boring tool thus takes a "bite" into the material, a portion of which can be removed by pulling or jerking the cable back a short distance. The procedure is followed until the entire obstruction is bored out and removed.

The advantage of such equipment lies in the fact that it can be operated from the street surface, whether the manhole is full of water or empty. Being flexible it is peculiarly fitted for sewers having bends and short turns and for the further reason that it can be operated effectively from manholes which are either deep or shallow.

Maintenance Practice

The following is the organization and practice adopted for maintaining more than 1,900 miles of sewers and drains in Baltimore: For the cleaning of inlets and manholes there is maintained a group of approximately 15 men divided into 5 small groups. Each group is equipped with a truck and assigned to a particular territory. A daily record is kept of their activities with the result that each inlet and manhole throughout the city receives attention at periodic intervals. Approximately twelve to fifteen hundred inlets are thus cleaned per week. A group of 20 men with four trucks is constantly employed in maintaining house connections and small lateral sewers, and a third group of 6 men and truck maintains the larger sized sewers and drains. By this method the City's sewers are kept under continuous maintenance, thereby reducing complaints, and eliminating inconvenience to property owners as much as possible. The Department maintains a complaint Division where complaints are received during office hours and arrangements are made to receive calls and render service until midnight. All complaints received during these hours are immediately transmitted to the various maintenance foremen for prompt attention.

No force is maintained after midnight as the number of complaints does not justify it, although in cases of storms and other emergencies we have an arrangement whereby the foremen and laborers can be communicated with promptly and detailed to the work.

Complaint Handling

When a complaint from a property owner is received that water is backing up through the sanitary fixtures, the complainant is advised to obtain the services of a registered plumber in order to determine whether the chokage is confined to the premises or is beyond the limits of private property. The reason for this is that the City of Baltimore maintains the main line sewers, and such portions of the house connection as are laid in public thoroughfares. By this policy expense to the city of investigating private property complaints is reduced to a minimum. Property owners are charged with the cost of removing chokages from sanitary house connections only, when the nature of the chokages indicates a misuse of the sewer. All main line chokages, and chokages in house connections resulting from tree roots, are cleared at city expense.

SEWER CLEANING WITH RUBBER BEACH BALLS

By A. M. RAWN, C.E.*

Los Angeles, Calif.

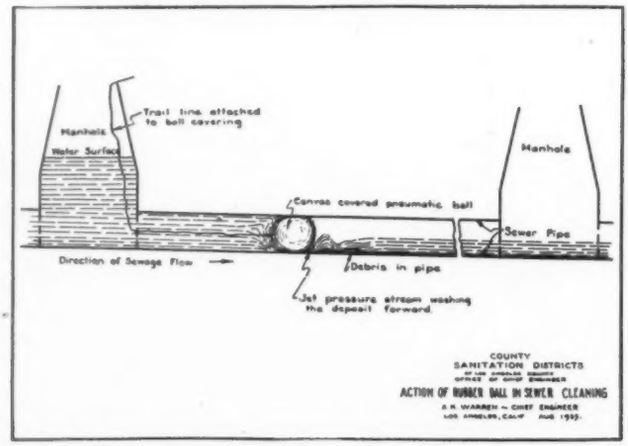
During construction of the sewer lines of the Los Angeles County Sanitation Districts, the problem of cleaning sand and debris from newly constructed lines gave rise to the trial of pneumatic rubber beach balls for this purpose. The use of beach balls was the outgrowth of the usual trial and error methods of using pull through devices, sluicing, use of fire hose and the like.

What is termed a beach ball in this narrative is the ordinary type of commercial pneumatic rubber ball commonly used at play grounds, at beach resorts and otherwise. The rubber is thin and the ball can be blown up to varying degrees of inflation at will. As furnished commercially, the balls have no covering and consist simply of elastic rubber. These balls are manufactured in sizes (diameters) of 6 to 30 inch diameter when fully inflated.

Procedure

For use in cleaning sewers the ball is first inflated and then wrapped in a covering of canvas or burlap, the edges of which are sewed together. A trail-line a little longer than the distance between manholes is then attached securely to the covering. The size of the ball and its covering should be such as to fit fairly snugly into the sewer leaving the downstream side of the manhole.

Immediately the ball is kicked into the pipe, sewage commences to back up in the manhole and continues to increase in depth until such time as its pressure is great enough to force water *under* the ball. (See sketch.) The ball then commences to move downstream through the pipe. Acting as a compressible floating plug it affords enough obstruction so that a continuous high velocity jet spurts under and to some extent around the balls, thereby sluicing all movable material ahead to the next manhole.



Sketch Showing Action of Beach Ball During Sewer Cleaning

Should the ball encounter an obstruction which is immovable (for instance a joint fin or the like), it merely indents to the necessary degree and moves forward. About the only fixed obstruction which will stop the forward progress of the ball is a root mass or some similar obstruction tightly wedged into the pipe. Brick, stones, bottles, loose metal parts, broken pieces of pipe, sand, gravel and settled sludge are easily moved ahead.

If the ball stops momentarily, a pull on the trail-line is usually sufficient to set it again in motion and if the pipe is quite dirty the trail-line can be snubbed to a step in the upper manhole and the ball's progress retarded to the required degree as the lower manhole is approached, thus giving time for complete removal of accumulated debris which the sewage has piled up ahead of the ball.

Much time may be saved by conserving the sewage pressure-head as the ball floats into the lower manhole. Just as the ball comes into view at the lower manhole, the snubbed trail-line is cast off and as the ball floats into the lower manhole with the gush of sewage, it is immediately kicked into the lower (outlet) pipe. The trail-line is picked up by fishing for it and the work proceeds as before.

In ordinarily dirty lines three men are employed as a crew and have cleaned in excess of four miles of sewer pipe in an eight hour working day.

The canvas covering serves two purposes: it permits ready attachment of the trail-line and also affords a measure of protection against puncture by razor blades, glass and sharp metal particles in the sewage sediment. The operation and maintenance crew carry along inner tube vulcanizing patches and small holes in balls are readily repaired on the job without much loss of time.

A Real Test

As a measure of the utility of this method of cleaning, one outstanding example will be noted. A 24-inch diameter reinforced concrete pipe inverted siphon carries the sewage of one main under the Los Angeles River flood control channel. The siphon is about 800 feet in length. A ball, with trail-line attached, was inserted in the upstream end of the pipe; and, although, it took thirty-six hours to work its way through, there appeared ahead of it about a truck load of sand, gravel, bricks and boulders as well as a half-dozen flash boards which had dropped into the sewer at the upstream gate. The ball was put through again immediately and appeared at the outlets in less than an hour.

*Asst. Chief Engr., Los Angeles County Sanitation District, Los Angeles.

SOME SEWERAGE OPERATING KINKS*

By A. M. RAWN[1]

Associate Editor

Sewer cleaning operations on a large trunk sewer system give rise to many notions and ideas regarding best methods. If given the opportunity, an intelligent operation and maintenance crew will probably develop that method which best suits the system upon which they are working. In time they will iron out difficulties incidental to their equipment and eventually may evolve something useful to their brethren elsewhere. In the hope that they have done the latter, the writer presents a few operation and maintenance "kinks" which have been evolved entirely by the field operation forces on the Los Angeles County Sanitation Districts' system. Nothing new is claimed for the ideas and many an operation man may recognize in each, or all, a counterpart of what he daily practices.

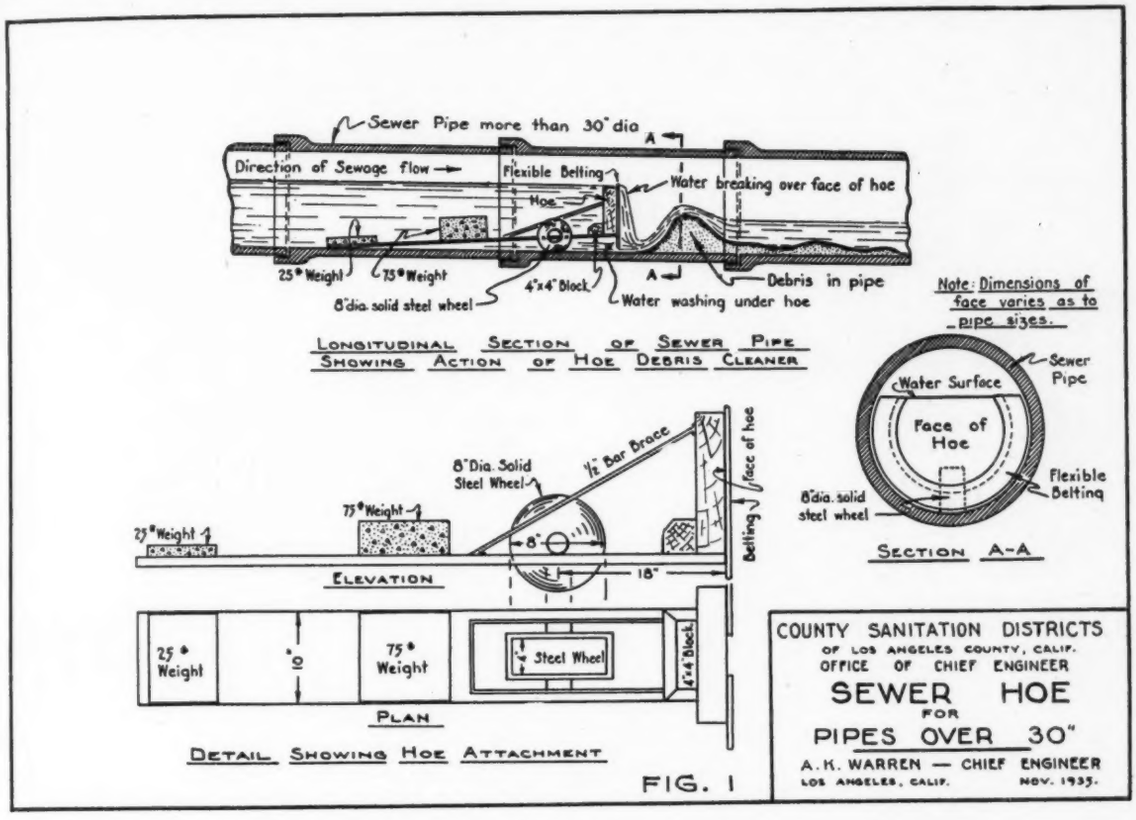


Fig. 1.—The Sewer "Hoe" for Cleaning Sewers Larger Than 30 In. Diameter.

Sewer Cleaning

The writer in the October, 1935, issue of WATER WORKS AND SEWERAGE described the use of rubber beach balls for cleaning lines up to 30 inches in diameter. Above 30 inches the balls are expensive and hard to obtain so that for cleaning circular sewers larger than 30 inches in diameter the district forces use a form of "hoe" shown as Fig. 1. It is simply and easily made and can be assembled in the ordinary manhole without much trouble.

In operation the "hoe" is assembled in the manhole and the proper sized flexible belting is attached to its downstream face. Belting is cut and fitted for each size of pipe from 30 inches to 60 inches for circular pipe, and is properly stiffened with sheet metal as is required in the larger sizes. With the exception of the belting attached to the face of the "hoe," the same equipment is used for cleaning all sizes from 30 to 60 inch pipe lines.

Following its assembly in the manhole, the "hoe" is thrust into the downstream pipe and the trail line is attached to the tail board holding the weights. The sewage backing up behind the "hoe" propels it through the pipe, moving any accumulated debris ahead to the manhole below.

The "hoe" is surprisingly efficient in cleaning the sides and invert of the line. Care must be taken to secure a reasonably close fit between the pipe and the outer edges of the belting so that the belting will have to flex forward to permit the escape of water collected behind the "hoe" face. If this precaution is taken, and the tail board is suitably weighted, one may be assured that just about anything movable below the backed-up water line will be shoved or sluiced ahead to the next manhole. Like the pneumatic

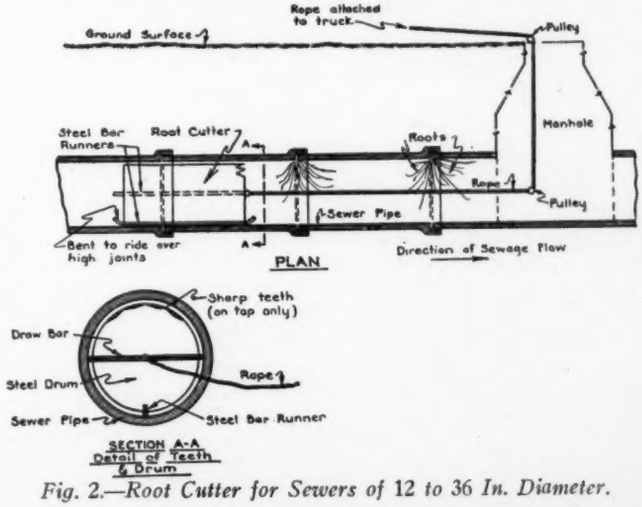


Fig. 2.—Root Cutter for Sewers of 12 to 36 In. Diameter.

*From WATER WORKS AND SEWERAGE, May, 1936.

[1]Assistant Chief Engineer, Los Angeles County Sanitation Districts, Los Angeles.

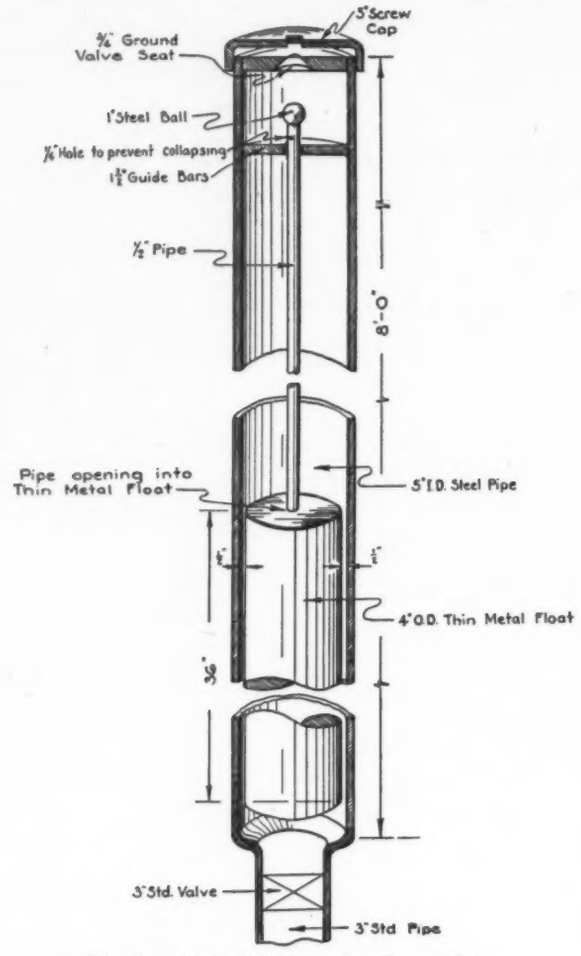


Fig. 3.—Air Relief Valve for Force Main.

cleaning ball, described in the October, 1935, issue of WATER WORKS AND SEWERAGE, the "hoe" moves easily over fixed obstructions.

Root Cutting

Many types of root cutters have been manufactured and sold. A number have been tried on the districts' lines. None of them, however, has proven much more efficient than the simple, inexpensive device shown herein as Fig. 2. It is simply and easily made of ordinary butt-welded steel pipe of commercial sizes.

To make it, take a piece of pipe about 18 inches long, serrate and sharpen the edges of both ends, and weld four shoes to the outside of the pipe. Affix halters for the pull and trail lines—and the job is done.

For an 8-inch line job use a 6-inch diameter pipe and ¼-inch strap runners or shoes. For a 12-inch line, use 10-inch pipe. A 12-inch diameter pipe is large enough for a 15-inch line, and so on. The sharpened notches in the pipe ends should be rather deep and wide so that they may pinch and hold the root, tearing or cutting it loose at its point of entrance into the line at which point it is usually quite small and relatively weak.

The pull line is thrust or pulled through with sewer rods, if it cannot be floated through the line. Pulley-blocks are then suitably arranged at the downstream manhole so that pulling may be done with the maintenance truck.

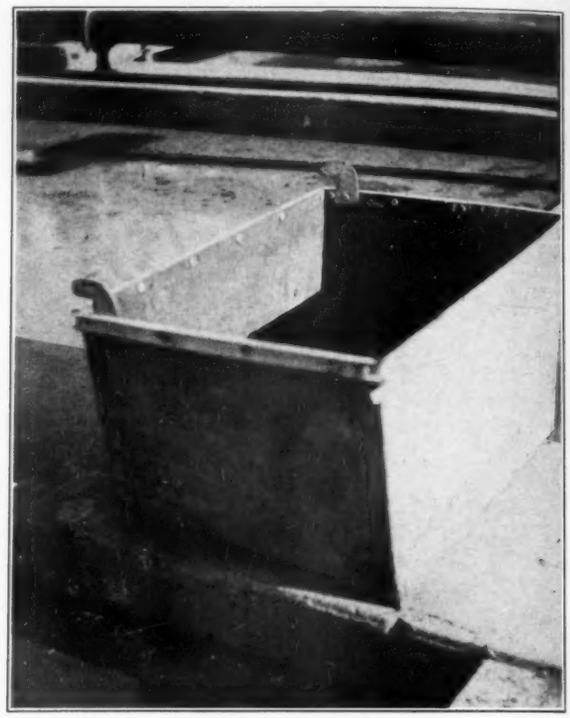
Lacking the proper diameter pipe for an operation, the operation and maintenance crew once manufactured a similar root cutter from a discarded water tank salvaged from a dump heap. It is still used upon occasion.

Air-Relief Valve

Figure 3 illustrates a type of air relief valve used in the 3½ mile (36-inch diam.) effluent pump line leading from the districts' sewage treatment plant. The valve pictured is installed at a summit in the line about 2,000 feet from the plant where air must be tapped off if the line is to operate efficiently. It is also important that none of the effluent escapes through the blow-off.

A number of valves were tried but all operated with indifferent success until that sketched was installed. As may be seen, it consists of a simple float operating a steel ball valve attached to the end of a section of ½-inch pipe. The ball seats in a ground valve seat tapered to catch and center the ball as it rises. The valve case is constructed from a 5-inch diameter, butt-welded, steel pipe.

The secret of the mechanism is the small hole drilled in the ½-inch pipe near the ball. This is to permit admission of air into the light metal float, equalizing the pressures inside and out on the float and preventing collapse of the thin metal cylinder. When first constructed the hole was omitted and the float promptly collapsed, rendering the valve ineffective. When rebuilt, the air inlet hole was drilled and the valve, operating about



Containers Placed Next to Tank Ready for Skimmings.

three times a minute, has been in continuous service for more than six months.

It may be thought that condensation or spray might eventually fill the float cylinder with water, and the writer admits having shared such a belief at one time. Convinced, however, by the plant chief operator who designed and built the valve, that if the float did eventually fill it could be easily drained and put back into service, the installation was permitted. Now it has been proven that the principle is sound. No water escapes through the valve.

Grease Collection and Incineration

At the district's treatment plant, grease is skimmed manually from the tanks and burned. For a number of years skimmings

Wheel Barrow Used for Transporting Skimmings Containers to Incinerator.

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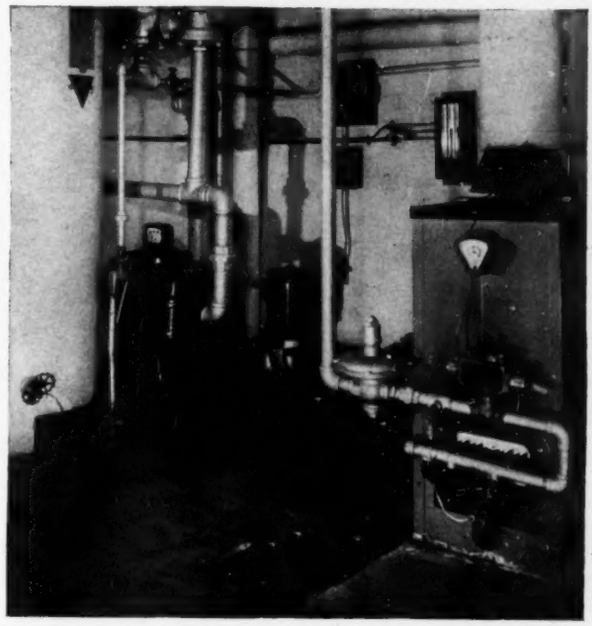

Typical of many **AGP** *installations in Sewage Treatment Plants. Shows 2-GA-7 Ideal Boiler used for heating sludge digestion tanks, and* **AGP** *Storage Water Heater 40C.*

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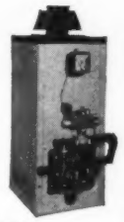
IDEAL GAS BOILER CAPACITY WITH SEWAGE DISPOSAL GAS

BOILER NO.		OUTPUT PER HOUR			INPUT PER HR.		BOILER SPACE		
								Floor Space	
Steam	Water	B.T.U per Hour	Sq. Ft. Steam A. G. A. Rating	Sq. Ft. Water A. G. A. Rating	B.T.U. per Hour	Cu. Ft. 700 B.T.U. Sludge Gas	Over-all Hght.	Width Front	Depth
.....	1-GA-4	31,500	.....	210	39,350	56	36 ¼"	14 ½"	22 ½"
.....	1-GA-5	42,000	.....	280	52,500	75	36 ½	14 ½	25 ½
.....	1-GA-6	52,500	.....	350	65,600	94	36 ¾	14 ½	28 ½
.....	1-GA-7	63,000	.....	420	78,750	113	38	14 ½	31 ½
.....	2-GA-4	63,000	.....	420	78,750	113	41 ¼	19 ½	22 ½
.....	2-GA-5	84,000	.....	560	105,000	150	41 ¼	19 ½	25 ½
.....	2-GA-6	105,000	.....	700	131,200	188	41 ¼	19 ½	28 ½
.....	2-GA-7	126,000	.....	840	157,500	225	41 ¼	19 ½	31 ½
.....	4-GA-9	168,000	.....	1120	210,000	300	41 ½	28	38
.....	4-GA-11	210,000	.....	1400	262,500	375	41 ½	28	44
.....	4-GA-13	252,000	.....	1680	315,000	450	41 ½	28	50
0-GS-4	.....	64,800	270	.....	81,200	116	52	23 ½	28
0-GS-5	.....	86,400	360	.....	108,000	154	53	23 ½	31
0-GS-6	.....	108,000	450	.....	135,000	193	53	23 ½	34
0-GS-7	.....	129,600	540	.....	162,000	232	53	23 ½	37
1-GS-4	1-GW-4	146,000	610	980	182,500	261	50	35*	33 ¾
1-GS-5	1-GW-5	186,000	775	1240	232,500	332	52 ½	39*	33 ¾
1-GS-6	1-GW-6	225,000	940	1500	281,500	402	53 ¼	43*	33 ¾
1-GS-7	1-GW-7	265,000	1105	1770	331,000	473	53 ¾	47*	33 ¾
1-GS-8	1-GW-8	305,000	1270	2030	381,000	545	54 ¾	51*	33 ¾
1-GS-9	1-GW-9	345,000	1435	2300	431,000	616	57 ½	55*	33 ¾
1-GS-10	1-GW-10	384,000	1600	2560	480,000	686	58 ¼	59*	33 ¾
1-GS-11	1-GW-11	424,000	1765	2820	530,000	757	58 ¾	63*	33 ¾
4-GS-6	4-GW-6	480,000	2000	3200	600,000	857	69	53	52
4-GS-7	4-GW-7	576,000	2400	3840	722,000	1030	69 ¾	58	52
4-GS-8	4-GW-8	672,000	2800	4480	840,000	1200	71 ¼	62	52
4-GS-9	4-GW-9	768,000	3200	5120	960,000	1372	72 ½	66	52
4-GS-10	4-GW-10	864,000	3600	5760	1,079,000	1543	75	70	52
4-GS-11	4-GW-11	960,000	4000	6400	1,200,000	1715	75 ¾	74	52
4-GS-13	4-GW-13	1,152,000	4800	7680	1,440,000	2060	69 ¾	85	64
4-GS-15	4-GW-15	1,344,000	5600	8960	1,680,000	2400	71 ¼	93	64
4-GS-17	4-GW-17	1,536,000	6400	10240	1,920,000	2740	72 ½	103	64
4-GS-19	4-GW-19	1,728,000	7200	11520	2,162,000	3090	75	107	64
4-GS-21	4-GW-21	1,920,000	8000	12800	2,400,000	3425	75 ¾	110	64
4-GS-22	4-GW-22	2,016,000	8400	13440	2,520,000	3600	71 ¼	136	64
4-GS-25	4-GW-25	2,304,000	9600	15360	2,880,000	4120	72 ½	148	64
4-GS-28	4-GW-28	2,592,000	10800	17280	3,240,000	4625	75	160	64
4-GS-31	4-GW-31	2,880,000	12000	19200	3,600,000	5145	75 ¾	172	64
4-GS-33	4-GW-33	3,072,000	12800	20480	3,840,000	5480	72 ½	186	64
4-GS-37	4-GW-37	3,456,000	14400	23040	4,320,000	6165	75	202	64
4-GS-41	4-GW-41	3,840,000	16000	25600	4,800,000	6850	75 ¾	218	64

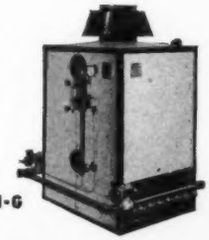
*1-*GS shown. The* 1-*GW is 4" shorter.*



Type 2-GA

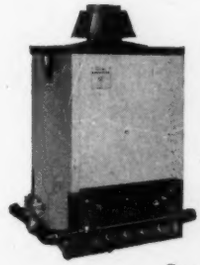
Type 1-GA

Type 4-GA



Type 1-G

Type 0-G



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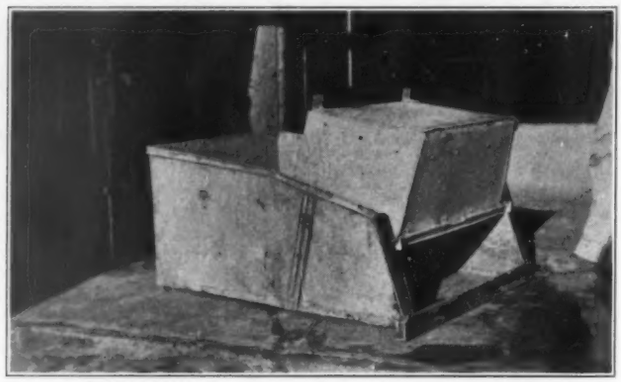


Storage Pan at Incinerator.

were accumulated in galvanized iron cans and transported to drainage beds. When drained they were picked up in wheelbarrows and conveyed to the incinerator.

Handling the galvanized iron cans was a dirty and expensive item of labor as was the spreading on drainage beds and the reaccumulation and transportation to the incinerator. The grease draining beds were odorous in spite of all precautions and the incinerator ash was about 90 per cent sand—the latter being picked up with the grease from the beds.

The chief operator requested and received permission to construct the containers and transporting barrow.

The container or pan may be made any convenient size. That shown holds about 3 cubic feet. Placed in the bottom of the pan and standing on a rigid framework which elevates it an inch off the pan bottom, is a ¼-inch square mesh screen, the purpose of which is to provide drainage for the skimmings. The pan is so constructed that all drainage is toward the 1½-inch pipe shown in the right front of the pan at the base. Drainage from the skimmings goes directly back into the sewage tank.

The pan is filled with skimmings as they are taken from the sewage and permitted to drain for a couple of hours before being taken to the incinerator. Twelve such pans are in use at the plant.

For transporting the pans to the incinerator the pneumatic tire wheel-barrow (illustrated) was constructed and is used. The operator wheels up to the high side of the pan, steps across it and engages the forward cross brace in the two forward pan dogs, then upon lifting the wheel-barrow handles, the rod welded across the back of the pan catches in the two swinging hooks attached to the barrow handles, and the load is securely engaged. The penumatic tire prevents wear on concrete walls and cross walks; makes for easy rolling.

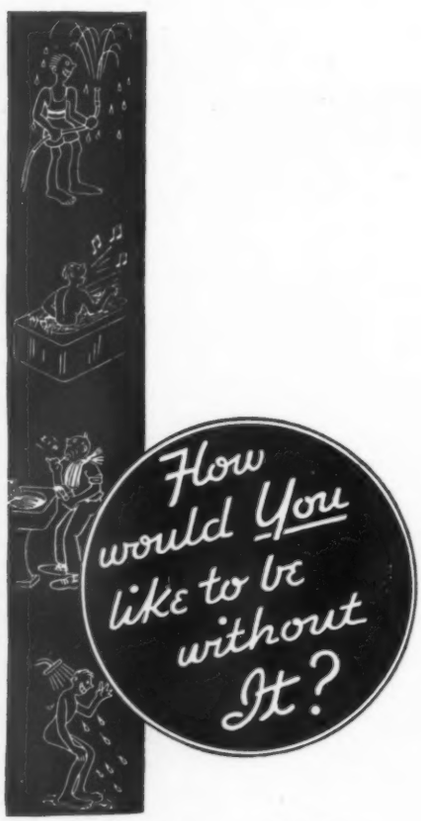
It may be seen that when the pan is lifted the slope of the pan bottom is reversed and any water shaken out of the screenings during transportation stays in the pan until it is set down.

At the incinerator a movable sheet metal storage pan is located in front of the charging door. The operator swings the loaded wheel-barrow handles over the storage pan, engages the pan's back rod in the two forward dogs in the storage pan, releases his load and then tips the screenings into the storage pan with a hook.

The operator's hands do not come in contact with the skimmings or the containers at any time and the curse has been eliminated from an operation job that was once a filthy task. Moreover, the work is greatly expedited.

The pans are cleaned daily with hot water and once a week with grease solvent. The pans and the wheelbarrow were all built in the plant shop by the plant operators.

Lest They Forget!
(A Message to Consumers)



"Pure water is the best of gifts that man to man can bring." —Lord Neaves.

The other day when I asked my little girl what water is she said, "It's what comes out when I open the faucet." This set me to thinking about how much all of us take for granted our water supply systems and the excellent service they give.

We have to be deprived of some things to realize what they mean to us. I have been thinking about our water works and what things would be like if it were to be permanently discontinued, if water no longer came from the faucet. The pictures aren't so rosy.

First, I would have to line up a source of water, for I could live but a few days without it. I would have to drill a well, collect rain water, or carry from a stream, pond or spring. At the best it would be a lot of expense or a lot of effort.

I would have to arrange to dispose of the sewage of my household. Again I run into expense and unpleasant conditions which are not nice to talk about.

It would be considerable more trouble to keep clean. Maybe the historic tub on the kitchen floor would have to be revived.

There would be no definite assurance that I would not be exposed to typhoid fever and other water-borne diseases which were such a scourge only a generation ago.

If my house caught on fire there would be much less chance of saving it and the other houses nearby. My family would not be so safe nor my sleep so peaceful.

Because of increased fire danger my insurance rates would jump, probably more than my total water bill. This is one advantage of water service most of us never think about.

In dry weather my lawn would turn brown and my garden would wilt for lack of water. It would be harder to wash my car, my front walk and even my dog.

After all, maybe we have let many years of "water from a faucet" dull our appreciation of a service which is so vital to our civilization and to our ability to live together in comfort, health and safety.

The Cover

The Message

The above leaflet, prepared for sending out with the water bill to customers, has proven popular with water works superintendents and managers. It was the idea of the Ford Meter Box Co., of Wabash, Ind., who printed thousands of free distribution to its customers, after which additional orders were filled at the cost of wholesale production. Many favorable comments have been heard on its value. The question on the cover is the "attention getting element" which every publicity man recognizes as a first essential.

Don't let your customers forget the importance of the No. 1 Utility.

THE EDSON CORPORATION

EDSON
Reg. U. S. Pat. Off.

Main Office and Works: 49 D Street, South Boston, Mass. **Established 1859**

NEW YORK: 142 Ashland Place, Brooklyn **Cable Address DIAPHRAGM, BOSTON**

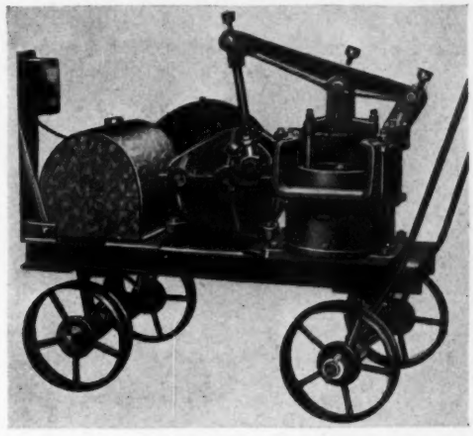
Manufacturers of Smallest and Largest Diaphragm Pumps in Market—FROM 2 in. suction with Open Discharge or 2 in. Suction Force Pump TO 4 in. Suction and Open Discharge or 4 in. Suction Force Pump.

"AV" POWER DITCH PUMPS

Unit	Eng.	Suction	Discharge	Capacity	Wt.
3RA1-2V	2 h.p.	3-in.	Open (Single)	4000 g.p.h	840
3RA2-3V	3 h.p.	3-in.	Open (Double)	8000 g.p.h.	1360
4RA1-2V	2 h.p.	4-in.	Open (Single)	6000 g.p.h.	900
4RA2-3V	3 h.p.	4-in.	Open (Double)	12000 g.p.h.	1520

HAND PUMP—SIZE NO. 1

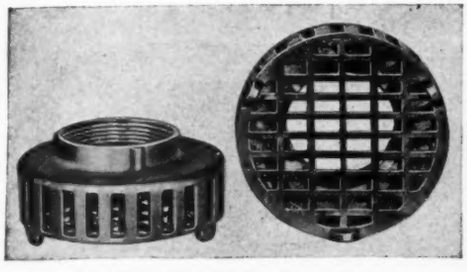
Smallest and most efficient non-chokable diaphragm pump made. Has 2-inch suction with open discharge and 1400 g.p.h. capacity up to 25 feet or more suction lift. Both valves brass and moulded rubber.



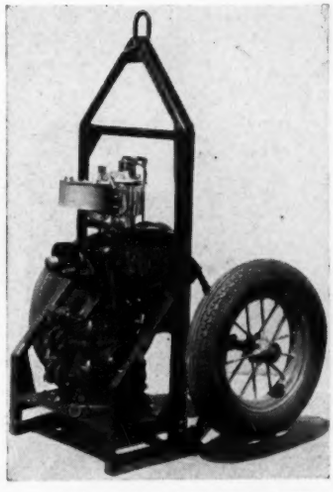
"RAE" ELECTRIC PUMPS

Unit	Motor h.p.	Suction	Discharge	Capacity	Wt.
3RAE1	2	3-inch (single)	open	4000	800
3RAE2	3	3-inch (double)	open	8000	1300
4RAE1	2	4-inch (single)	open	6000	850
4RAE2	3	4-inch (double)	open	12000	1460
3RME1	2	3-inch (single)	3-inch	4000	850
3RME2	3	3-inch (double)	3-inch	8000	1480
4RME1	2	4-inch (single)	4-inch	6000	940
4RME2	3	4-inch (double)	4-inch	12000	1630

Motor to Suit Your Electric Current



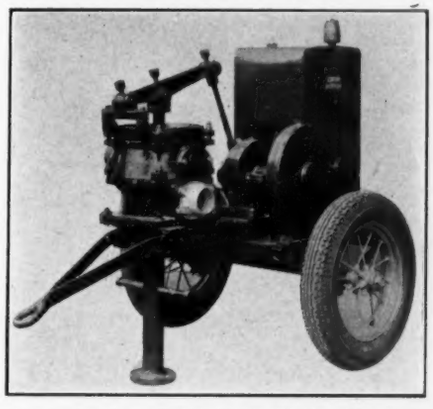
BRONZE STRAINER—FIG. 30A
Sizes 1½" to 6"



"ON TOP" TRAILER PUMP

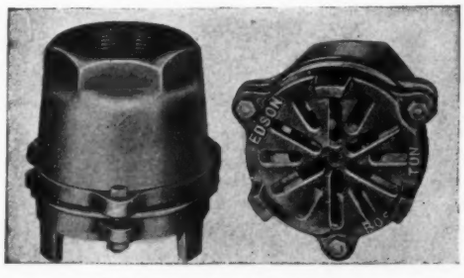
Dimensions with Trailer Upright
Height 70", Width 48", Depth 40"

Unit	Suction	Discharge	Capacity	Weight
OM-T	3-in.	3-in.	4000 g.p.h.	680
OA-T	3-in.	open	4000 g.p.h.	635

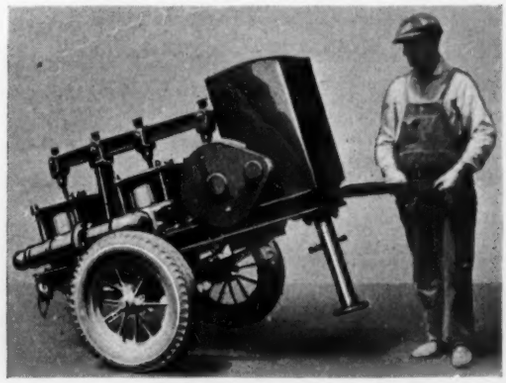


"UT" HEAVY DUTY PUMPS (SINGLE)

Unit	Suction	Discharge	Capacity	Wt.	Code
3RMI-UT	3-in.	3-in.	4000 g.p.h.	1075	Prebend
4RMI-UT	4-in.	4-in.	6000 g.p.h.	1150	Precept
3RAI-UT	3-in.	Open	4000 g.p.h.	1025	Precinct
4RAI-UT	4-in.	Open	6000 g.p.h.	1140	Precise



GALVANIZED FOOT VALVE
BRONZE FLAT STRAINER
FIG. 2332
Sizes 1½" to 4"



"UT" HEAVY DUTY PUMPS (DOUBLE)

Unit	Engine	Suction	Discharge	Capacity	Weight
3RA2-UT	3 h.p.	3-inch	Open	8000 g.p.h.	1580
4RA2-UT	3 h.p.	4-inch	Open	12000 g.p.h.	1720
3RM2-UT	3 h.p.	3-inch	3-inch	8000 g.p.h.	1700
4RM2-UT	3 h.p.	4-inch	4-inch	12000 g.p.h.	1850

EDSON SPECIAL SUCTION HOSE
With Heavy Bronze Couplings and Flexible Bronze Clamps

EDSON HAND TRENCH PUMPS

Size	Suction	Capacity	Weight
No. 2	2½-in.	1800 g.p.h.	122 lbs.
No. 3	3 -in.	4000 g.p.h.	176 lbs.
No. 4	4 -in.	6000 g.p.h.	247 lbs.

POWER UNITS SKID, TRUCK OR TRAILER MOUNTED

Also Manufacturers of Edson Pump Diaphragms, Suction Hose, Suction Strainers, Foot Valves, Adapters, Hydrant Pumps, Hydrant Protectors, Pump and Hose Accessories.

Specify Style of Pump and Size, with Length of Hose and receive our quotation on a COMPLETE EDSON PUMP OUTFIT.

HOURLY LOAD VARIATIONS IN RELATION TO SEWAGE TREATMENT PLANT OPERATION

By ELSON T. KILLAM

Consulting Engineer, Tenefly, N. J.

The wide variations in the hourly load arriving at sewage treatment plants, due to the combined effect of variations in sewage strength and in rate of sewage flow, have previously been discussed by the writer.[1]

Data then available were confined to two plants, both located in Georgia. Investigations recently conducted on two systems in New Jersey involving widely different conditions than those of the two systems originally described, indicate surprisingly similar load variations.

Tests of 24-hour duration with frequent flow readings and separate analysis of hourly or two-hourly samples emphasize the following conditions in these four systems:

(1) A substantial portion of the total daily load arrives at the plant in a comparatively short operating period—see curves.

(2) The hourly variations and per cent of the total daily load arriving at the plant in any given period are not markedly different regardless of whether the load be expressed in terms of flow and B.O.D. content—or, expressed in terms of flow and suspended solids content.

(3) Load variations from hour to hour are surprisingly uniform regardless of the size of the system or other factors which might normally be expected to create widely different conditions.

(4) Hourly distribution of load and variations therein have important effects on plant efficiency and on operating procedure with many types of treatment plants, particularly chemical plants. These variables emphasize the desirability of providing for flexibility in design to allow variable operation.

Studying the Load Variations

A convenient method of summarizing sewage load variations is by means of cumulative load curves. To obtain data for such a curve, samples should be collected throughout a full 24-hour

[1] "Hourly Load variations as a Factor in Sewage Treatment Plant Operation"—WATER WORKS AND SEWERAGE; July, 1934; pp. 237-240.

TABLE NO. 1 — DATA RELATIVE TO CUMULATIVE LOAD CURVES

Curve Number	Location of System	Type of District Served	Average Flow—M.G.D.	Estimated Tributary Population	Date of Test Period	Distance from Sampling Point to Most Remote Point in System—Miles	Method Flow Measurements (*)	Data Relative to Samples
"A"	DECATUR, GA. (Shoal Creek Outlet Sewer)	Strictly Residential; Separate System	0.167	2,200	4 p. m., Sat., Oct. 28 to 4 p. m., Sun., Oct. 29, 1933	2.5	90 deg. V Notch Weir	(a)
"B"	RAHWAY, N. J. (Rahway Valley Joint Trunk Sewer for 7 Municipalities)	Separate System; Residential, with some Industries and some Business Districts	1.84	23,000	3 p. m., Mon., July 23 to 3 p. m., Tues., July 24, 1934	7.8	90 deg. V Notch Weir	(a)
"C"	ELIZABETH, N. J. (Elizabeth Valley Joint Trunk Sewer for 12 Municipalities)	Separate System; Residential, with some Industries and some Business Districts	14.19	228,000	2 p. m., Thur., Aug. 2 to 2 p. m., Fri., Aug. 3, 1934	18.0	Venturi Meter	(b)
"D"	ATLANTA, Ga. (Main Sewer Entering Peachtree Creek Plant)	Combined System; Residential, with some Industries and some Business Districts	15.22	110,000	8 a. m., Fri., May 3 to 8 a. m., Sat., May 4, 1933	8.0	Recording Gage at Station Rated by Current Meter	(a)

* All Flow Readings at half-hour intervals.
(a) Samples collected at half-hour intervals—each group of four composited and analyzed.
(b) Samples collected at half-hour intervals—each group of two composited and analyzed.

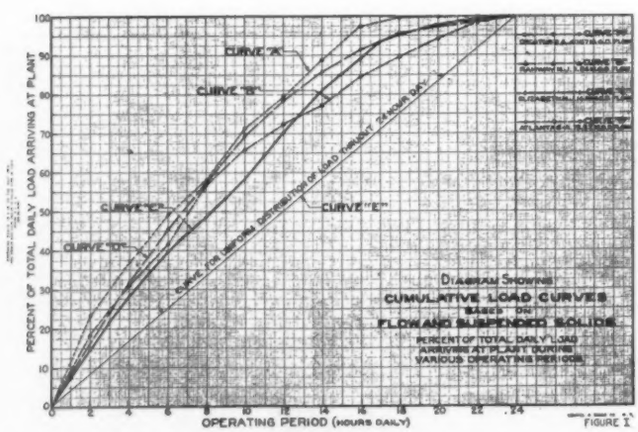

CURVE "A"
CURVE "B"
CURVE "C"
CURVE "D"
CURVE "E"
CURVE FOR UNIFORM DISTRIBUTION OF LOAD THROUGHT 24 HOUR DAY
DIAGRAM SHOWING
CUMULATIVE LOAD CURVES
BASED ON
FLOW AND SUSPENDED SOLIDS
PERCENT OF TOTAL DAILY LOAD ARRIVING AT PLANT DURING VARIOUS OPERATING PERIODS
PERCENT OF TOTAL DAILY LOAD ARRIVING AT PLANT
OPERATING PERIOD (HOURS DAILY)
FIGURE I

Fig. 1—Cumulative Loads, Based on Floc and Suspended Solids

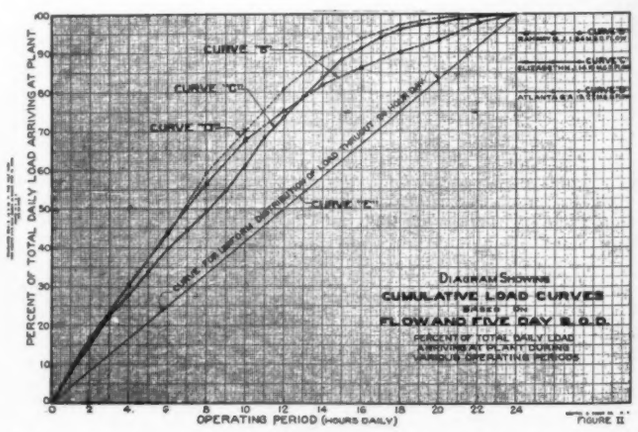

CURVE "B"
CURVE "C"
CURVE "D"
CURVE "E"
CURVE FOR UNIFORM DISTRIBUTION OF LOAD THROUGHT 24 HOUR DAY
DIAGRAM SHOWING
CUMULATIVE LOAD CURVES
BASED ON
FLOW AND FIVE DAY B.O.D.
PERCENT OF TOTAL DAILY LOAD ARRIVING AT PLANT DURING VARIOUS OPERATING PERIODS
PERCENT OF TOTAL DAILY LOAD ARRIVING AT PLANT
OPERATING PERIOD (HOURS DAILY)
FIGURE II

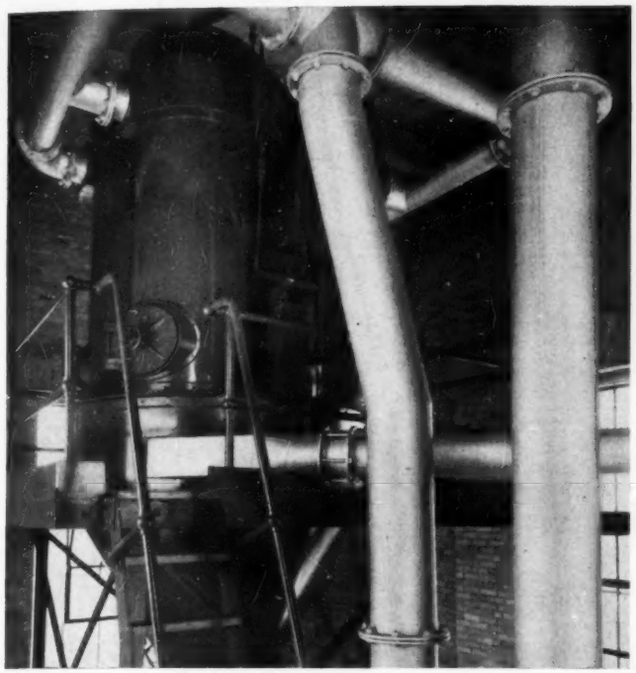
Fig. 2—Cumulative Loads Based on Flow and 5-Day Oxygen Demand

FULLER COMPANY

CATASAUQUA, PENNSYLVANIA

Chicago: 1118 Marquette Bldg. San Francisco: 320-321 Chancery Bldg.

THE AIRVEYOR CONVEYING SYSTEM



Airveyor Filter installed at the new Coney Island Sewage Disposal Plant, Coney Island, New York.

The Airveyor is used extensively for unloading fine, crushed, and granular materials such as lime, soda ash, alum, bauxite, ferric sulphate, and many others, from cars, ships and barges. Also for reclaiming from bulk storage and stock piles. Hundreds of these systems are in daily service. Materials can be conveyed economically over long distances to avoid interference with buildings, equipment and traffic. They are furnished in vacuum, pressure, and combined types, in a full range of capacities to meet any plant requirement. For fine or dusty materials automatic filters are available in several types.

Some advantages and economies are:

Savings by purchasing in bulk

Minimum handling and storage cost

One man operation

Simple and inexpensive storage facilities; the Airveyor will recover from all types, open stock piles or enclosed steel bins

First cost sufficiently low to warrant investment

Maintenance requirements are negligible

Simple plant layout; installation can be made without interrupting present operation

Absolute cleanliness

FULLER ROTARY AIR COMPRESSORS AND VACUUM PUMPS

Single and two-stage Compressors and Vacuum Pumps are available in a full range of capacities up to 1800 C.F.M. at standard motor speeds . . . working pressures up to 125 lb. gage . . vacuums up to 99 per cent of barometer.

These machines have many advantages that make them unique and adaptable to various applications. Some of these features are:

Extraordinary capacity with reference to size, weight, and floor space requirements. This makes possible the installing of separate compressors at point of use, eliminating a large central compressor plant with its network of air line and consequent losses.

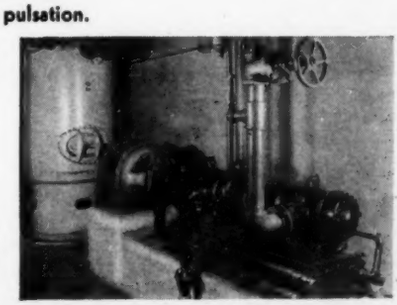
Direct drive at common motor and gas engine speeds without reduction gearing.

Few working parts; no valves.

Maintenance requirements are negligible, with the ability to operate continuously at full loads for long periods without mechanical attention.

Air flow free from pulsation.

All parts readily accessible.



Fuller Rotary Two-Stage Compressor installed in a mid-western incinerator plant; one of three Fuller Compressors in use at this same plant.

FULLER-KINYON, FLUXO, AND AIRVEYOR CONVEYING SYSTEMS · · · ROTARY FEEDERS AND DISCHARGE GATES
ROTARY AIR COMPRESSORS AND VACUUM PUMPS · · AUTOMATIC BATCH WEIGHERS · · BIN SIGNALS

the hour at maximum load, and subsequently taking each consecutive hourly load in order of descending magnitude, and plotting of 24-hour curve. Loads expressed in terms of flow and suspended solids content, or flow and B.O.D. content, or both, way be used for the study.

Typical examples of such curves, showing data for the four systems investigated, are shown in Figures 1 and 2, the former being based on load determined by suspended solids content and flow, and the latter upon B.O.D. and flow.

Statistics, showing the type of system, average daily flow, tributary population, and other information, for the four systems investigated, are shown on Table 1.

period, preferably at intervals of 15 minutes or ½ hour. These samples should be proportionate to the flow and each group of samples comprising a period of one or two hours' duration should be separately analyzed. It is also essential to take flow measurements at frequent and coincident intervals. In this way the total pounds of suspended solids or B.O.D. arriving at the plant during each hour of the day, may be ascertained. Cumulative load curves may then be constructed by selecting, first,

Similarity in Load Variations

In view of substantial differences in type and size of the four systems referred to in Table 1, the relatively small difference in the load developed in any given number of hours in each of the systems, is of especial interest.

The Decatur (Ga.) system, for instance, involved a sewage flow of only 0.16 m.g.d. with a population of only 2,200 people in a strictly residential area, and with the most remote point in the area served only 2½ miles from the point of sampling on the trunk sewer.

On the other hand, the Elizabeth Valley System involved a total flow of 14.19 m.g.d. from a tributary system comprising several hundred miles of sewers serving 228,000 people. Remote portions of the system are at least 18 miles distant from the point at which flow measurement and samples were taken.

It might well have been expected that in such an extensive system as the latter, the variations would be smoothed out and greatly reduced in magnitude before the sampling point was reached by the passing flow. Comparison of all four curves, however, indicates that in no instance, within a fixed number of hours of operation, does the total cumulative load arriving at the plant vary by more than 13 per cent. Examination of the curves also discloses that the distribution of the load, based on suspended solids, agrees very closely with the load based on 5-day B.O.D.

What It Means

The similarity of these curves indicates that load variations in substantial proportions may be expected on every sewerage system. These variations and their effects are accordingly important in the design and operation of sewage treatment plants; in the measurement and evaluation of treatment plant efficiency; and, in the collection of river samples below sewer outlets during investigations of the pollution of receiving streams.

KILLING ROOTS IN SEWERS WITH COPPER SULPHATE

By J. W. McAMIS

Superintendent Water Works and Sewerage, Greenville, Tenn.

Roots give a great deal of trouble in the smaller sewers, by causing stoppages wherever they may happen to find an entrance into the pipes carrying domestic sewage.

For four or five years now we have been using copper sulphate to combat this trouble.

We have a man whose duty it is to visit each manhole in the system at least once each month, looking for stoppages. He carries along on these trips a small bag or bucket of copper sulphate and drops a small handful of crystals down into the flowing sewage wherever he finds that the stoppage is downstream.

Specimen of Sewer Choker. This "Bush" Supported by a Single Feeder

After a reasonable amount of experience in this work a man can tell pretty well where trouble is to be expected in the near future, by the nature of the flow of the sewage and by the conditions in the bottom of the manhole.

In cases where stoppage is due to roots, sewage will back up into the next manhole above during periods of greatest flow during the day and will recede during periods of low flows. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulphate crystals *while the sewage is still flowing,* a sufficient concentration of the poison will usually reach the seat of the trouble to eliminate it before the stoppage is complete.

At Greenville, we have the same man doing this work that looks after the disposal plants and he tells me that he can predict almost exactly when the balls of roots will turn loose and come down to the treatment plant following the copper treatment.

Since we have been using this scheme it is a rare day when we have to send out a truck with sewer-rods and other equipment to open up a stopped sewer.

NOTE: The above operating "kink" appeared in the March, 1933, issue of WATER WORKS AND SEWERAGE. In reply to an inquiry, Mr. McAmis makes the following comments in April 1936:

"Regarding the exact quantity of the sulphate required for good results, I have attempted no determination of the necessary concentration of copper sulphate. However, it is my opinion that the length of the contact period is a more important factor than the actual concentration of the copper sulphate. To illustrate; the ideal condition seems to be where a small flow of sewage, say two to five g.p.m., is just trickling through a mass of roots. In a case like this a small handful of the chemical applied in the manhole just upstream from the stoppage will do the trick.

If the flow is greater, as determined from looking in the manhole just below the stoppage, greater quantities and possibly repeated applications would be necessary. If it is kept in mind that it is time of contact that is important, rather than the amount of copper sulphate, no trouble should be experienced in carrying out this operation.

Another important point to remember is that it is useless to apply the copper sulphate in a sewer that is completely stopped, for unless there is at least a small flow of sewage through the obstruction there is no chance for contact between the roots and the copper solution. Sewer rods would be the only remedy here—at least to start some flow through and allow the copper to reach the roots." (Since it is only necessary to kill the small root which enters the sewer, and not the great mass of roots branching from it, the important factor is that of reaching the feeder root with the killing chemical. Then, the flow pulling on the large heavy "brush", causes the weakened base root to break. Prechlorination of sewage has been found to produce the same results on root infected sewers but is not so simply applied as the copper treatment.—Ed.

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PRODUCTS—"AQUA NUCHAR" ACTIVATED CARBON

RECENT DEVELOPMENTS IN THE USE OF ACTIVATED CARBON IN SEWAGE TREATMENT

ROBERT W. HAYWOOD

Industrial Chemical Sales, Division West Virginia Pulp and Paper Company, New York City

One of the most rapidly advancing phases in the protection of public health is the field of sewage treatment. Improvement in plant design, more accurate and reliable control of operations, the selection of better trained operators, and the development of new treatment processes all contribute to vastly improved conditions. Leading the field in new processes is the application of activated carbon as an aid in plant operation. Although this treatment is in its infancy as far as time is concerned, reports from plants using it indicate definite benefits that have been derived from its application and suggest others that, while not proven as conclusively, still must be considered to get a complete picture. It is the purpose of this article to present these facts, together with a few, brief remarks explaining them, to those interested.

Types of Plants

Activated carbon has been used successfully in the following types of sewage treatment plants:

1. Primary settling with separate sludge digestion, with and without gas collection, and with and without trickling filters and secondary settling.
2. Imhoff tanks with trickling filters, with and without secondary settling tanks.
3. Activated sludge plants with primary settling and separate sludge digestion.
4. Activated sludge plants with vacuum sludge de-watering.

Benefits Derived

Improved operation in the above types of plants resulted from the application of activated carbon but the same results were not obtained in every kind of plant even though, in some instances, the type of treatment was the same. Broadly, these benefits can be divided into three classes, namely, improved digestion, improved settling, and odor control.

These three classifications may be broken down into the following individual improvements:

1. Improved digestion
   - A. Increased temperature of sludge in digestors.
   - B. pH control of sludge.
   - C. Increased gas flow.
   - D. Improved gas quality.
   - E. More rapid drying sludge with increased drainability.
   - F. Decrease in odor of sludge.
2. Improved settling
   - A. In primary settling tanks.
   - B. Decrease of scum in gas vents of Imhoff tanks.
   - C. Decrease of scum in separate sludge digestors.
3. Odor control
   - A. In gas vents of Imhoff tanks.
   - B. Over-all plant odor controlled.
   - C. Control of odor from humus tank sludge.

The above list is a compilation of results obtained from a number of plants. It is not to be expected that every benefit will result in the use of carbon in any plant since local conditions vary widely and have major effects on the final outcome. The list is presented simply to show what has been accomplished so far among some of the more important users of activated carbon. These plants are mentioned in the following discussions of the various improvements listed above and the information presented was obtained by the writer during a personal visit with the operator of each plant.

pH Control

Control of the hydrogen ion concentration (pH) of the sludge is an important step in maintaining optimum conditions for digestion. Until recently this was accomplished by the addition of hydrated lime to the sludge as it was pumped to the digestors but activated carbon has replaced lime successfully in some plants. Perhaps the two outstanding plants where this was done are the activated sludge, separate sludge digestion plant at Newark, N. Y., and the primary settling, separate sludge digestion plant at Walden, N. Y.

Records from the Walden plant prove that activated carbon enabled the operator to raise the pH of the sludge from 6.6, a point beyond which he had been unable to increase it even though fifty pounds of hydrated lime were used every day for this purpose, to a maximum of 7.6 between December 17, 1935, to February 29, 1936. To do this thirty-five pounds of carbon were applied daily to an average of 160 cubic feet of sludge just as it was pumped to the digestor. This amount was later decreased until, starting May 17, the average dose was between 3 and 4 pounds per 160 cu. ft. of sludge pumped, the pH being held at 7.0 with this amount. It should be mentioned that the digestor was not operating satisfactorily during the period of lime application but has given no trouble since carbon has been used.

Sludge Drying

Poorly digested sludge dries slowly under the best possible conditions and, oftentimes, fails to reach a condition that will allow its removal from the drying beds before the beds are needed for more sludge. This means either that the sludge must be removed in an unsatisfactory, hard-to-handle condition or the digestors must continue to hold the second batch, thus decreasing their efficiency and over-loading this part of the treatment process. That the use of activated carbon in the digestion process would increase sludge drying was conclusively proved at both Liberty, N. Y., and Fairport, N. Y., the time required at Liberty for sludge to dry sufficiently to be removed from the beds being cut approximately in half. Of particular interest was the effect of this material on the sludge in the secondary settling tanks at Fairport. Here it was necessary to clean these tanks every two weeks until carbon was used when this period was lengthened to five weeks and the sludge removed was practically odorless, drying without difficulty.

Odor Control

A poorly digested sludge is usually one with decidedly objectionable odors but, unfortunately, sludge is not the only source of odors at a sewage plant. Septic raw sewage, scum in primary and secondary settling tanks, and scum in the gas vents of Imhoff tanks are other potential sources of odors. Not only did the sludge at Liberty and Fairport dry more rapidly but it had a decidedly decreased odor. This was also at the Tryon Park Sewage Treatment Works at Rochester, N. Y.

This plant is situated in a residential section and consists of Imhoff tanks, sprinkling filters, and final treatment tanks. The sludge is drawn off in lagoons and, prior to the use of activated carbon, the atmosphere of the entire neighborhood following each drawing was extremely objectionable. Here carbon is mixed with water to form a slurry and poured directly into the gas vents of the Imhoff tanks. This past summer (1936) there have been no complaints about odors.

Both Albion and Wanakah, N. Y., have been able to control odors from the gas vents of Imhoff tanks by applying activated carbon as part of the routine treatment. At Albion the carbon was first mixed with water to form a slurry, poured in the vents, and mixed by hosing. At Wanakah the carbon was mixed with hydrated lime and dusted into the gas vents as a dry powder once a day during the warm weather months. The Wanakah plant is interesting in that it is in a residential section on the shore of Lake Erie and is quite close to the nearest dwelling. No complaint of odors were received after this treatment was adopted.

Gas Production

Both Newark and East Rochester, N. Y., report increased gas yields. At Newark the average gas yield per day for 211 days prior to the use of carbon was 7220 cubic feet. With carbon this figure increased until the average yield per day for 186 days was 8750 cu. ft. Recently experimental work has been started at Pottstown, Pa., to learn more about the effect of carbon on the gas yield, as well as other effects the carbon may have on sewage treatment.

Scum Reduction

Certain benefits have already been demonstrated at the Pottstown plant where carbon is fed into two of four parallel primary settling tanks. The carbon treated tanks definitely had less floating matter in them and were cleaner, as a whole, than the untreated tanks. Scum was also reduced in the gas vents of the Imhoff tanks at Albion, this being an additional benefit derived from the treatment of these tanks as described above.

Nor has scum reduction been confined to the two types of treatment already mentioned. Fairport, N. Y., reduced scum in the digestor materially by using activated carbon. On March 19, 1936, the temperature of the unheated digestion tank was 50° F., the ash content of the sludge was 32.4%, organic content 67.6%, and the grease content 12.2%. The addition of activated carbon was begun and, by March 30th, 140 pounds had been added by preparing a slurry and introducing it into the discharge side of a sludge circulating pump, thus insuring a thorough mixing of the carbon with the sludge. In one week the temperature of the digestor rose to 54° F., and the grease content increased to 19.8%. Carbon was added at the rate of 10 pounds per day until April 25th when the temperature had risen to 56° F., and the grease content to 31.2%. The highest grease content was noted on May 8th when the sludge contained 32.45%. In view of the fact that grease forms a major portion of scum, it seems logical to assume that the increase of this constituent in the sludge could only have come from that source since the nature of the sewage did not change materially during the time carbon was used and, since the application of carbon was stopped, the quantity of grease in the sludge decreased to its original value.

Activated Sludge Bulking

Activated carbon was used successfully to correct conditions of sludge bulking at High Point, North Carolina. During the month of July and half of September, 1936, it was applied to the mixed liquor in the mixing chamber ahead of aeration tanks at a rate of approximately 4 p.p.m. which resulted in a noticeable shrinkage in sludge blanket in the settling basins and a decrease in the volumetric solids with improvement in vacuum filter operation.

Application and Dose

Experiences have indicated that no hard and fast rule can be laid down as to the correct point of application for activated carbon nor the best dosage. These factors are dependent on local conditions in the plant where its use is proposed as well as the work it is expected to do.

In general, carbon should be applied to the incoming sewage just after it passes the coarse screens and, if applied at this point, the maximum benefits may be expected with regard to odor control in the plant as a whole and increased solids deposits in the primary tank (in the case of primary settling) or in the sludge hoppers of Imhoff tanks. If applied here the carbon will be mixed more thoroughly with the sludge and scum and grease control will be more positive. However, in some cases it may be better to apply carbon at other points. If the source of objectionable odors are gas vents in Imhoff tanks, the most economical and practical point of application would be these vents. If carbon is used to improve digestion only it may be wiser to apply it to the sludge as it is pumped to the digestors. Each plant presents a different problem that can be answered correctly only when all the influencing factors are known.

Doses reported so far vary from three to five parts per million, based on the raw sewage flow. These are average figures but should serve as a starting point from which adjustments may be made as seem necessary.

Activated carbon will do the work required of it best if applied correctly and intelligently. Some type of feeding equipment is essential if the maximum benefits are to be derived and, of course, the more accurate the dosage, the more consistent the results. Either wet or dry feed machines are suitable. There is available for a small cost a simplified, wet feeder that was designed especially to feed activated carbon in sewage treatment. Details of this machine can be obtained from our New York office on request.

Conclusion

As has been said, the use of activated carbon in sewage treatment plants is relatively new and there remains a lot to be learned. It is safe to say that at this point it has a definite and important place in the picture and is here to stay.

SEWAGE AND SLUDGE PUMPING[1]

By HENRY RYON[2]

Albany, N. Y.

General

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

[1]From a paper presented before the N. Y. State Sewage Works Ass'n.—1935.

[2]Senior Sanitary Engr., N. Y. Dept. of Public Works.

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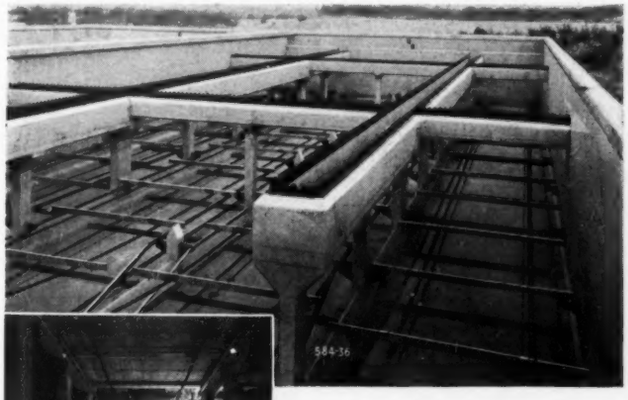
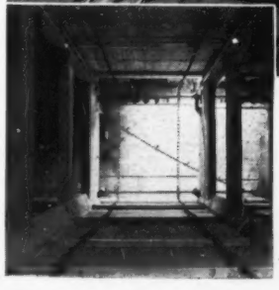
Airplane view of the new Jeffrey-equipped Columbus, Ohio, sewage treatment plant.

By continuing development Jeffrey equipment is made to meet each new rise in the standards demanded by progress. Jeffrey sewage treatment equipment has proved its merit in many of the largest plants in the country . . . by outstanding performance, with power economy and low-cost maintenance.

Our sanitary engineers, intimately familar with all phases of sewage and water treatment, will be glad to submit recommendations.





Above, a section of the secondary settling tanks in the Columbus plant. View at the left shows a section of the primary tanks showing the Jeffrey sludge collectors.

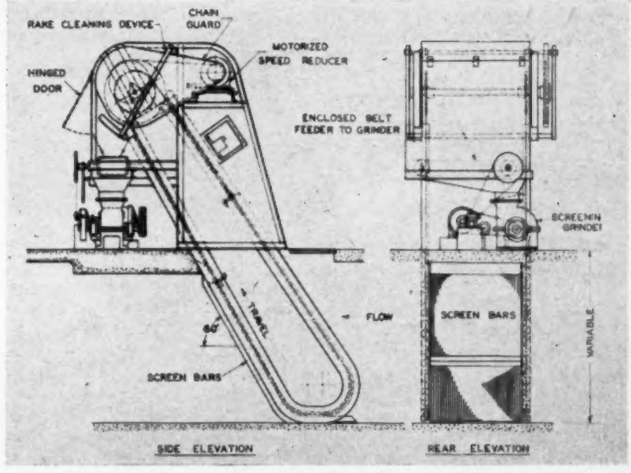
Send for Catalog No. 615-E.

Bar Screens

The improved Jeffrey mechanically cleaned bar screen is fully automatic with features not found in other sewage screens. When working in conjunction with a Jeffrey screenings grinder (see drawing below) it is a highly efficient way of disposing of sewage screenings.

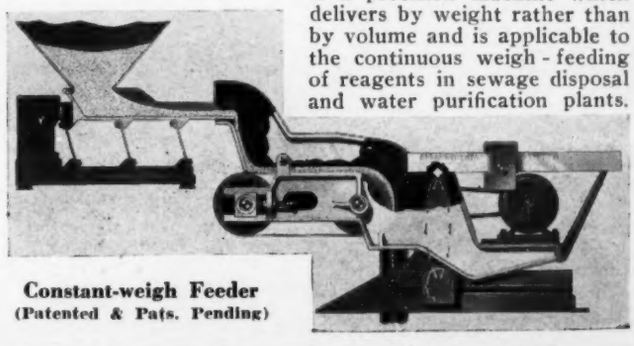
The Jeffrey screen has no sprockets and shafts at the bottom . . . clear openings on the sides do away with obstruction in submerged portion.

Jeffrey Combined Screen and Grinder



Unusually flexible, the Jeffrey screen and grinder unit may be designed to suit any depth or width of channel and may be installed at any angle from 45° to vertical.

The Jeffrey-Traylor "Waytrol" is a precision machine which delivers by weight rather than by volume and is applicable to the continuous weigh-feeding of reagents in sewage disposal and water purification plants.



Constant-weigh Feeder
(Patented & Pats. Pending)

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multi-stage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a common suction header must for the same reason be made

MERCO-NORDSTROM VALVE COMPANY

Subsidiary of

PITTSBURGH EQUITABLE METER COMPANY

General Offices at Pittsburgh, Pa.

FACTORIES—Pittsburgh, Hopewell, N. J., Tulsa, Okla., and Oakland, Cal.

BRANCH OFFICES AND SALES AGENCIES: Buffalo, Philadelphia, New York, Columbia, Pittsburgh, Chicago, Saginaw, Davenport, Memphis, Kansas City, Tulsa, Atlanta, Houston, Oakland, Los Angeles

Water, Oil, Gasoline and Grease Meters; Regulators; Lubricated Plug Valves

Nordstrom Valves are well adapted to the requirements of Sanitation Departments for use in sewage disposal plants because of their leak-resistant, non-sticking and positive shut-off construction. Made in a wide range of sizes and for various pressures.

Phantom View

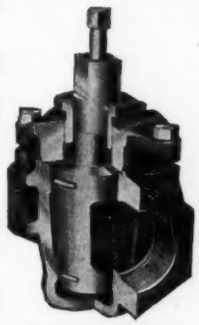
"SEALDPORT" LUBRICATION— The "Sealdport" method of valve lubrication forces Nordstrom Lubricant under high pressure between the plug and body, making the valve leak-resistant and freeing the plug to assure easy operation. Simply turning a screw at the top of the valve completely covers both seat and plug surfaces with a film of lubricant.

Lubricant grooves in the valve body and plug are so arranged that the lubricant cannot be blown from the valve by the fluid or pressure in the line.

The Nordstrom method of "Sealdport" lubrication has made practical the use of plug cock valves as large as 30" in size and assures the most satisfactory service for sewage disposal plants.

In the phantom view, shown above, the lubricant grooves on the plug and in the valve body may be clearly seen. These grooves form an interconnecting system which conducts the lubricant to the lower end of the plug in either open or closed positions of the valve.

The principle of high pressure "Sealdport" valve lubrication may be easily traced through the entire valve in the phantom view.



Cutaway Model of Nordstrom Lubricated Plug Valve

At right is shown plug assembled within valve body and with the especially designed gland and yoke in place. Should neglect to lubricate occur, valve will remain tightly seated because all unbalanced pressure is in a downward direction and can be readily freed by inserting a stick of Nordstrom Lubricant and turning down the screw.

EMCO-Nordstrom Valve

EMCO - NORDSTROM LUBRICATED PLUG VALVES

These valves have standard gate valve face to face dimensions and embody all the advantages inherent to the general Nordstrom line, including the patented "Sealdport" method of lubrication and plug lifting features that make operation easy and positive at all times. It is now economical to replace valves of other types with these lubricated plug valves since they can be installed without altering existing pipe dimensions.

EMCO METERS FOR SEWAGE GAS

It has become common practice in the design and operation of sewage disposal plants to utilize the gas generated during sludge digestion as a source of heat and power. Since modern engineering methods have demonstrated that accurate measurement is a necessary part of the control of any process, the metering of this gas is an important matter and the choice of meter, one that should be given careful consideration.

EMCO No. 2½, 3 and 4 Meter

Experience has proven that the conventional meter used for measuring manufactured and natural gas will not operate satisfactorily on this type of service due to the destructive effect which sewage tank gas has on materials commonly employed in the construction of gas meters. For this reason EMCO Meters for Sewage Gas are especially constructed from materials which laboratory tests have proven resistant to the action of this gas. The outer case is of heavy cast iron with interior coated with a special preparation. The working parts are made from stainless steel, lead nickel silver, tinned brass, or illium, depending on the operation each has to perform, while a special tannage and treatment is given to the diaphragms.

The amount of gas obtained from sludge digestion is naturally variable depending on the disposal process used, climatic conditions and type of population served. EMCO engineers have a complete file of valuable statistics based on years of experience with this type of measurement and will be pleased to make recommendations as to the size and type of meter best suited for any particular installation.

EMCO Sewage Gas Meters are made in a full line of sizes to take care of any volume requirements.

EMCO No. 4½ and 5 Meter

SPECIFICATIONS OF EMCO METERS FOR SEWAGE GAS

Meter No.	Size of Conns., Inches	Length, Inches	Width, Inches	Height, Inches,	Weight, Pounds	Capacities* Cu. Ft. per hour of .6 Specific Gravity Gas ½" Pressure Absorption	Capacities* Cu. Ft. per hour of .6 Specific Gravity Gas 2" Pressure Absorption
0	¾, 1 or 1¼	9 7/16	8¾	11¾	38	175	350
1	1, 1¼ or 1½	11⅛	9⅛	14¼	46	275	550
2	1¼ or 1½	12¾	10⅛	16⅝	67	350	700
2½	2	20⅜	14	25⅛	227	850	1800
3	2 or 3	22½	16½	27 1/16	305	1200	2500
4	3 or 4	27¼	19¾	32⅞	506	1700	3800
4½	4	33¼	17 7/16	42 1/16	675	3000	6000
5	4	40	20¾	51⅛	1000	5000	10000

*Note: Capacity ratings of gas meters are usually based on a gas of .6 Specific Gravity. To correct for gas having a higher or lower gravity, the following formula should be used:

$$R_g = R \frac{\sqrt{.6}}{\sqrt{G}}$$ where: R_g = rating for gas having specific gravity G; G = specific gravity of the gas; R = rating in table above

at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Sludge Pumps

Both centrifugal pumps and reciprocating pumps have been successfully used for pumping sludge. Where the quantity of sludge is large, the centrifugal pumps with suitable non-clogging impellers are probably the more satisfactory. In many cases, such as pumping sludge from the bottom of a settling tank, it is desirable to draw the sludge slowly and regulate the rate carefully to prevent drawing the upper layer of fresh sludge, or even the supernatant liquid through the digested sludge in the bottom of the tank. Except in the largest sewage disposal plants this may be difficult with a centrifugal pump. If a small sized pump is used, it is apt to clog. If a large sized pump is used it will generally be necessary to decrease its capacity at times. Throttling the discharge of a sludge pump for this purpose is obviously undesirable. Motors with variable speed transmissions by means of which the pump speed may be varied without varying the motor speed, while rather expensive, may be used very satisfactorily for this purpose. Centrifugal sludge pumps must of course be set below the water level in the suction well if priming difficulties are to be avoided.

For the above reasons the reciprocating pump is probably better adapted for sludge pumping in small sewage disposal plants. Where the lift is high and it is not necessary to vary the capacity, the ordinary single acting triplex pump, with ball valves, has proved very satisfactory. Where the lift is low and it is necessary to vary the flow, as is usually the case, the diaphragm pump or the plunger pump with large diameter cylinders, designed especially for handling sludge, is usually preferable. The present tendency seems to be toward the use of the plunger pump in preference to the diaphragm pump. At the Hudson River State Hospital sewage disposal plant, where the 10-inch diaphragm pumps are used about three hours daily, the diaphragms have to be renewed every six months.

On the other hand, at this same plant, where 10-inch plungers are used, the packing, under continuous operation, has to be renewed every three months. These pumps may have one or more cylinders. The pumps with two or more cylinders give a more even discharge and also a more nearly even load on the motor, but the single cylinder pumps serve satisfactorily in most cases. Where lime is fed into the pump suction the surge in the suction line caused by the single cylinder pump sometimes causes trouble. Different capacities may be obtained with these pumps by varying the length of the stroke. This is done on some pumps by using an eccentric on the main shaft which is adjustable to give any stroke from zero to the maximum. On the other pumps several holes are provided in the crank so that the stroke may be changed by inserting the connecting rod pin in the proper hole. In some cases two and three speed motors have been provided with pumps of this type to further increase the possible number of capacities. The stroke of a diaphragm pump can generally be varied from 0 to 3 inches while that of a plunger pump can generally be varied from 2 to 5 inches. Shear pins are usually provided to release the motor should any hard material stop the plunger. It is well to keep the speed of reciprocating pumps rather low if smooth operation is desired. Speeds of over 30 or 35 revolutions per minute will usually cause vibration although manufacturers often recommend higher speeds. The valves may be of the ball or of the flap type. The ball valves usually show less tendency to collect solids than the flap valves, but are not entirely free from clogging. Rags will pack under the balls and sometimes clog the valve chamber entirely. Special easily removable caps are generally provided on the valve chambers so that the valves will be readily accessible for cleaning. In this connection it might be well to note that if an air chamber, or alleviator, is provided on the discharge line the discharge shut off valve should be between the air chamber and the pump or a special drain valve provided for the air chamber. Otherwise the sludge in the air chamber will be blown out through the discharge valve chamber when the cap is removed for cleaning or repairs. Pumps of the reciprocating type need not be set as low as centrifugal pumps because they prime more readily.

Friction of Sludge in Pipe

Where the suction and discharge lines are long it is often necessary to consider the friction loss in the pipes when the sludge is passing through them. Considerable has been written on this subject but there is as yet no standardized formula for computing the loss. The loss for a sludge with a high water content is about the same as for water but increases as the water content decreases until it often reaches 1½ times the loss for water. The loss is sometimes figured by using a coefficient of 60 or 70 in Chezy's formula instead of the 100 usually used for water.

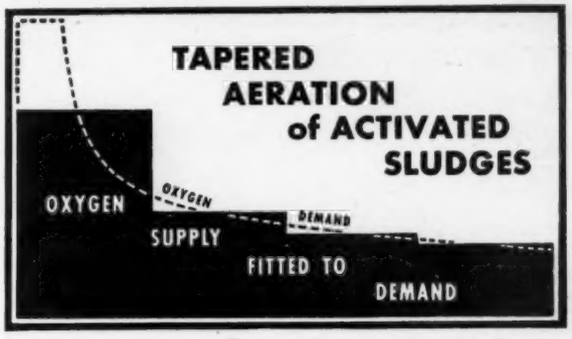
Motive Power

At the present time most pumps are driven by electric motors. It was customary a few years ago to provide auxiliary gasoline engines as a source of power when the electric power failed. Usually, however, when the electric current failed, the service was restored before the operator could start his neglected gasoline engine. With the use of underground transmission lines and inter-connected power stations, failure of electric current has been so reduced that the auxiliary engines are now being omitted in most stations. Gasoline engines, oil engines and steam engines can, however, be used satisfactorily for driving pumps where electric current is not available.

CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

MECHANICAL AERATORS
SWING DIFFUSERS
COMMINUTORS
SCRU-PELLER PRIMARY SLUDGE PUMPS
FLUSH-KLEENS FOR LIFT STATIONS
NON-CLOG SEWAGE PUMPS
SEWAGE SAMPLERS
ODEEOMETERS



COMMINUTOR

ELIMINATES—Screenings and Screenings Disposal

PREVENTS—Odors and Flies

Cuts Coarse Sewage Matter Into Small Settleable Solids Without Removal from the Channel

SAMPLES
IN PROPORTION
TO FLOW

Fig. 2175 (Left)—True-Test Sewage Sampler

Two types: Stationary and Portable. Three types of control: Manual, automatic by float, and automatic by flow meter. Ask for Bulletin 128-G.

Figure 1795—Water Seal and Meter Seal Pumping Unit
Ask for Bulletin 128-E

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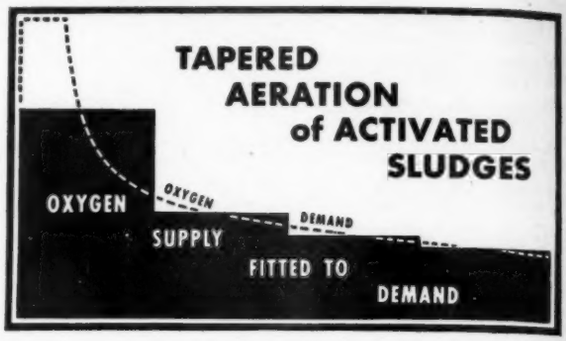
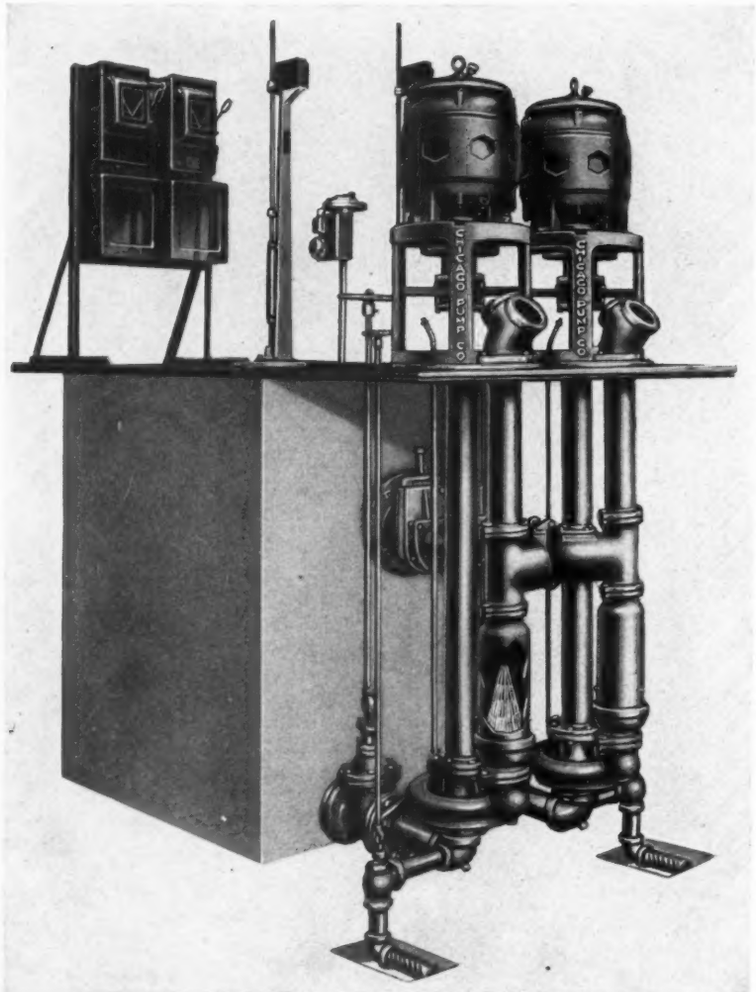


The "Flush-Kleen" Is the Only Sewage Pump That Can Handle Small Capacities Without Clogging

Most Reliable Sewage Pump Made

Automatically Backwashes Strainer



Ideal for Lift Stations

Keeps Solids From Basin and Pump

Submerged and Dry Basin Types

Impeller Handles WATER ONLY

How the "Flush-Kleen" Operates

"Flush-Kleens" are installed in duplex sets, with an "Automatic Alternator" to transfer the operation from one pump to the other. Only one pump operates at a time, except in extreme emergencies.

While one pump is operating, sewage flows into the basin through the idle pump and through an overflow strainer. This prevents sewage from backing up in the sewer line.

Coarse sewage matter is stopped by the strainer in the idle pump and is held in the strainer chamber built in the discharge pipe of the pump, only water passing into the basin.

When the idle pump starts operating, the accumulation of coarse matter in the strainer chamber of the pump is flushed out with the water, just like backwashing a filter, and is discharged into the sewer. The check valve in the inlet is forced shut when the pump starts operating. This prevents the pump from discharging back through the inlet line.

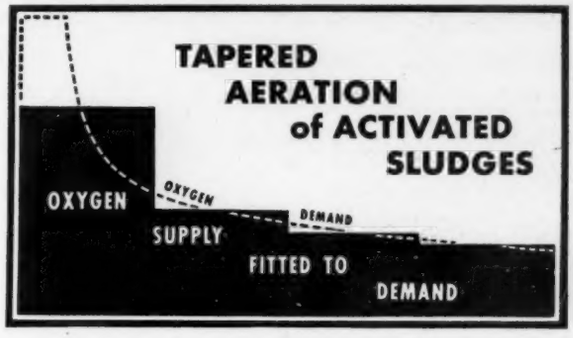
Each pump is float-controlled, and the "Automatic Alternator" transfers the operation from one pump to the other.

"Flush-Kleens" are the only reliable sewage pumps for handling small capacities. They will not clog and require no attention, except periodical lubrication.

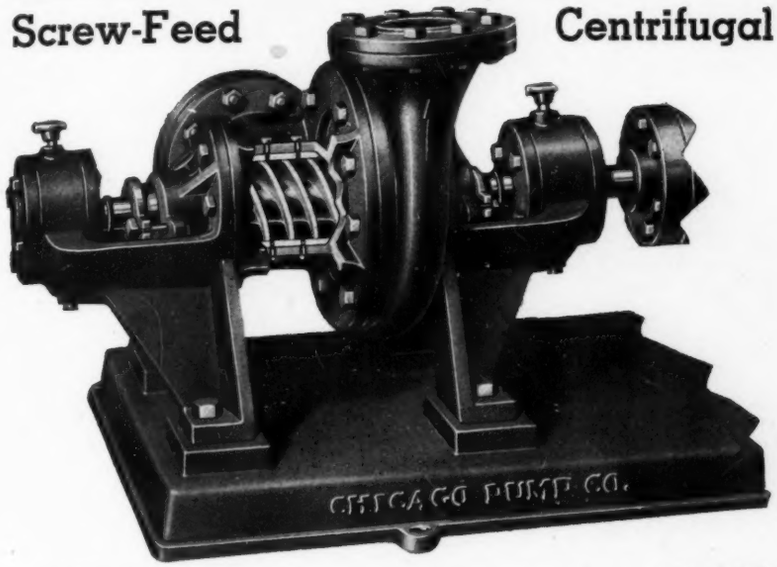
CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

MECHANICAL AERATORS
SWING DIFFUSERS
COMMINUTORS
SCRU-PELLER PRIMARY SLUDGE PUMPS
FLUSH-KLEENS FOR LIFT STATIONS
NON-CLOG SEWAGE PUMPS
SEWAGE SAMPLERS
ODEEOMETERS



Screw-Feed Centrifugal



"SCRU-PELLER" Primary Sludge Pump

Fig. 1860 (Left).—The Chicago "Scru-Peller" Sludge Pump which was designed especially for pumping Primary Sludge. The casing has been cut away in this picture to show the screw conveyor in the suction ahead of the impeller. The capacity can be varied instantly from maximum of the pump all the way down to 1 G.P.M. Stellited cutters prevent clogging. Ask for Bulletin 128-D.

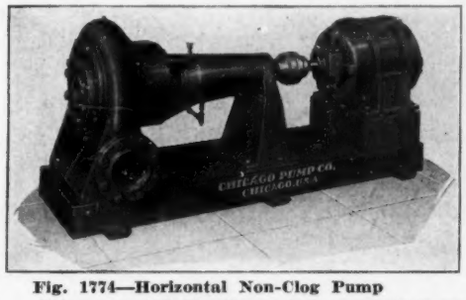


Fig. 1774—Horizontal Non-Clog Pump

Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

Fig. 1765—Vertical Pedestal-Mounted Non-Clog Pump

High motor is flood protection. Pump occupies only about one-third floor space as horizontal unit. Bulletin 127.

Fig. 1731-1—Vertical Open-shaft Non-Clog Pump

Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

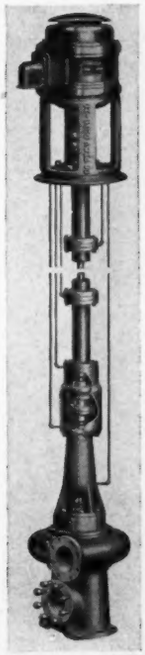


Fig. 2502 — Vertical Protected-Shaft Non-Clog Pump

Flexible mounting at floor plate and flexible coupling at pump compensate for misalignment. Ask for Bulletin 126.

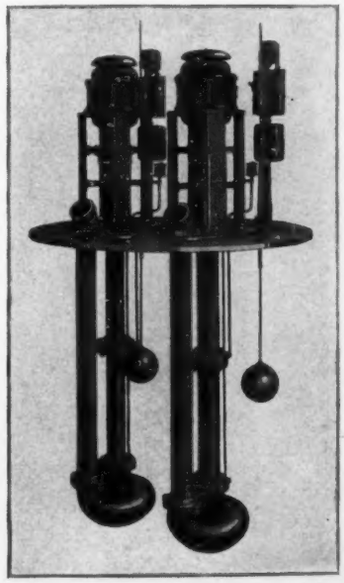


Fig. 2087—Duplex Vertical Enclosed-Shaft Non-Clog Pumps

Tongue-and-groove construction insures perfect alignment. Ask for Bulletin 124.

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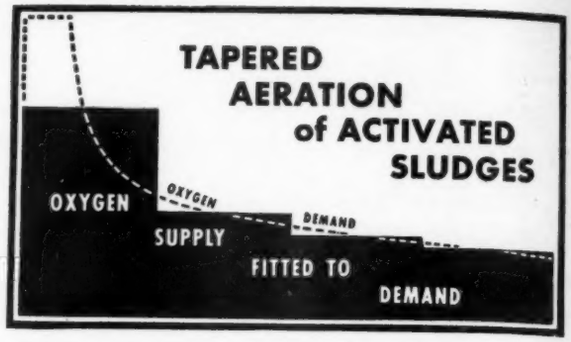
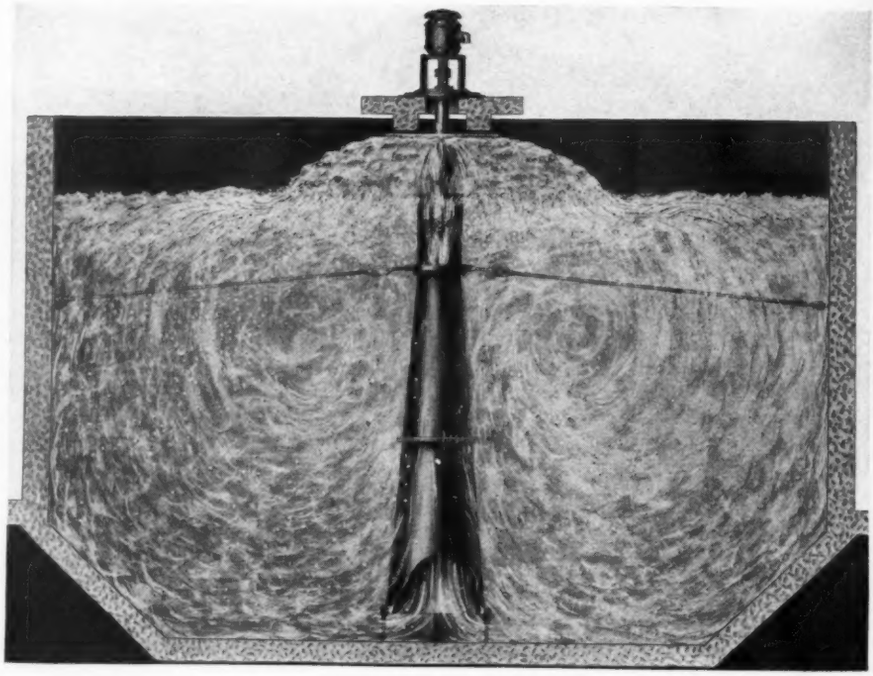


MECHANICAL AERATORS and SWING DIFFUSERS

Especially Designed for Operation on Tapered Aeration Principle

Fig. 2312 (Right) — "Chicago" Mechanical Aerator for complete treatment of sewage by the Activated Sludge Process. Flora, Ill., installation giving 98 per cent reduction of a domestic sewage of 570 p.p.m., 24-hr. average (5-day) B.O.D. Power consumption of 0.337 Kilowatt hours per pound of B.O.D. reduced, measured on the primary effluent of 330 p.p.m. B.O.D. Ask for Mechanical Aerator Bulletin 128L.

Chicago Pump Co. also manufactures the Swing Diffuser which has the following exclusive feature: Clogged or defective diffuser tubes may be raised out of tank for servicing without draining the tank. "Chicago" air diffusion equipment delivers more oxygen per cu. ft. of air supplied. Ask for Bulletin 128-M.



COMBINATION AERATOR-CLARIFIER

FOR SMALL TOWNS

Fig. 2307 (Left)—"Chicago" Combination Aerator-Clarifier for Activated Sludge Sewage Treatment Plants serving populations between 100 and 4,000. Performs aeration and clarification simultaneously in a single tank. Effects sewage purification up to 98 per cent. Requires less than two hours manual supervision daily. Ask for Bulletin 128-K.

OPERATING CONTROL TESTS FOR THE ACTIVATED SLUDGE PROCESS

By T. R. HASELTINE
Sanitary Engineer† Kansas City, Mo.

The first requirement of the activated sludge process is the maintenance of dissolved oxygen in the aeration tanks. As early as 1926, Harris, Cockburn and Anderson[1] stated this principle of the process very clearly. Their work proved that "the dissolved oxygen adsorbed by the sludge is a constantly decreasing amount from its contact with the inflowing sewage to its discharge from the reactivation channels. The *starting point* of the process of reactivation may be accepted as the point nearest the inflow of the aeration tank at which dissolved oxygen first appears. The degree of reactivation that takes place in the aeration tank is dependent upon the balance maintained between the supply of, and the demand on, the dissolved oxygen and the period of detention as timed from the determined starting point."

Every operator of an activated sludge plant must know that the process is dependent upon aerobic bacterial action. Therefore, it should be evident to all that the presence of dissolved oxygen in the aeration tanks is a prime requisite for the proper functioning of the process. In spite of its self-evident nature some operators may lose sight of this principle of the process, due perhaps to their efforts to comprehend and apply the never-ending stream of articles dealing with the relative merits of pH control, various types and designs of structures and equipment, or the use of chemicals as an adjunct to the process. It is, therefore, very refreshing to read Mr. Anderson's timely and extremely logical articles[2, 3, 4] on the operation and control of the Rockville Center activated sludge plant. It was those articles that led the writer to prepare the following discussion for publication in WATER WORKS AND SEWERAGE that carried Mr. Anderson's two articles.

"Tapered Aeration"

The "tapered aeration" effect while not new in principle, is worthy of far more widespread application than it now receives. The writer operated the Salinas, California, plant[5] from 1930 to 1933. During that time we found, after extensive experimentation, that the best results were obtained by so adjusting the air distribution that (a) there was an appreciable amount of dissolved oxygen in the sludge reaeration compartments, (b) there was at least a small amount at the inlet of the aeration compartments, and (c) the dissolved oxygen gradually increased towards the outlet of the aeration compartments. This required the use of from 55 to 70 per cent of the total air applied in the first half of the aeration tanks. The percentage increased some with high sewage flows, low air supplies, or bulked sludge and visa versa.

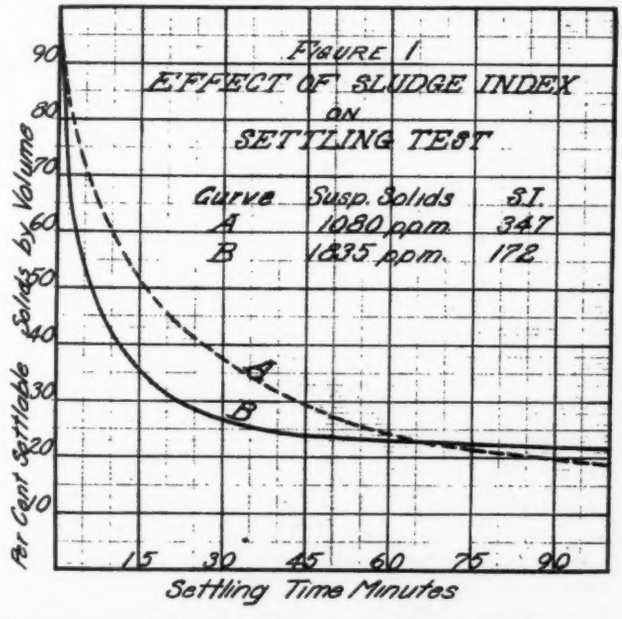


Fig. 1.—The Effect of Sludge Density (Sludge Index) on the Volumetric Sludge Settling Test.

Dissolved Oxygen Tests

To maintain "tapered aeration" it is, as Mr. Anderson points out, necessary to make frequent dissolved oxygen (D.O.) determinations throughout the aeration tanks. However, the writer marvels at the success of Mr. Anderson[4] in using the regular Winkler method for such determinations; first, because one would expect interference from nitrites and, second, because it has been our experience that the sludge floc adsorbed some of the reagents and masked the end point of the titrations. We doubt if the operators of many activated sludge plants would find the regular Winkler method satisfactory. The Report of the Committee on Methods of Sewage Analysis[6] states that "as a rule nitrites will occasion erroneously high results when present in amounts exceeding 0.1 p.p.m. of N. as nitrite. Interference due to nitrites may be expected in dealing with effluents from biological oxidation devices." Whenever the presence of nitrites is suspected the report recommends the use of the permanganate modification of the Winkler method. At Salinas our crude sewage had an organic-plus ammonia nitrogen content of about 65 p.p.m. Our final effluent usually contained from 0.2 to 3.0 p.p.m. of nitrite nitrogen. As might be expected we found the regular Winkler method valueless under such conditions; in fact, we had to use a double strength permanganate solution much of the time.

The accurate determination of the dissolved oxygen in the mixed liquor of the aerators is extremely difficult and requires special apparatus such as was devised by Theriault and McNamee.[7] They state that the usual technique of working only on supernatant liquor from settled sludge gives low results (not subject to empirical correction) due to the high oxygen demand of the sludge itself. However, the writer believes that with proper care it is entirely permissible (for routine plant control) to work on a supernatant liquor and thus avoid the complications of sludge floc or the use of special equipment. It is always desirable to have a margin of safety in plant operation and the errors pointed out by Theriault and McNamee are on the side of safety.

At Salinas we collected samples of mixed liquor from various points throughout the aerators in 2 liter bottles. The bottles were completely filled, stoppered and allowed to stand until 270 m.l. of fairly clear supernatant liquor could be siphoned off into small bottles. The permanganate modification of the Winkler method was then used to determine the dissolved oxygen content of these smaller samples. Ordinarily 5 to 15 minutes' standing of the 2 liter samples would result in sufficient clarification although at times of severe bulking as much as 40 minutes elapsed before the small samples could be siphoned off. On several occasions we siphoned off a second small sample an hour or two after taking the first one and repeated the D.O. determinations. The decrease in dissolved oxygen in the supernatant over the elapsed time was surprisingly small even though the liquor had been underlain by sludge all that time.

Second Operating Requirement

The necessity of maintaining an adequate supply of dissolved oxygen in the aerators at all times, when coupled with the desirability of keeping the power expenditure for aeration at a minimum, leads directly to the second operating requirement—namely, that of keeping the oxygen demand of the mixed liquor at a minimum. The oxygen demand of the mixed liquor is in part due to that of the sewage and in part due to that of the sludge. However, that of the sludge is so much the greater, that of the sewage becomes almost negligible. Grant, Hurwitz and Mohlman[8] proved in the laboratory that (a) mixtures of sewage plus sludge absorb oxygen in proportion to the weight of sludge but with increasing amounts of sludge most of the oxygen demanding material of the sewage is coagulated or adsorbed by the sludge so that very little oxygen is required for the unadsorbed material, and (b) small amounts of sludge reduce the B.O.D. of the sewage almost as rapidly as do larger amounts. Their findings have since been proven in many full scale plants.

It is, therefore, the problem of the operator to first determine

*From WATER WORKS AND SEWERAGE.
†With Chas. A. Haskins, Consulting Engineer, Kansas City, Mo.

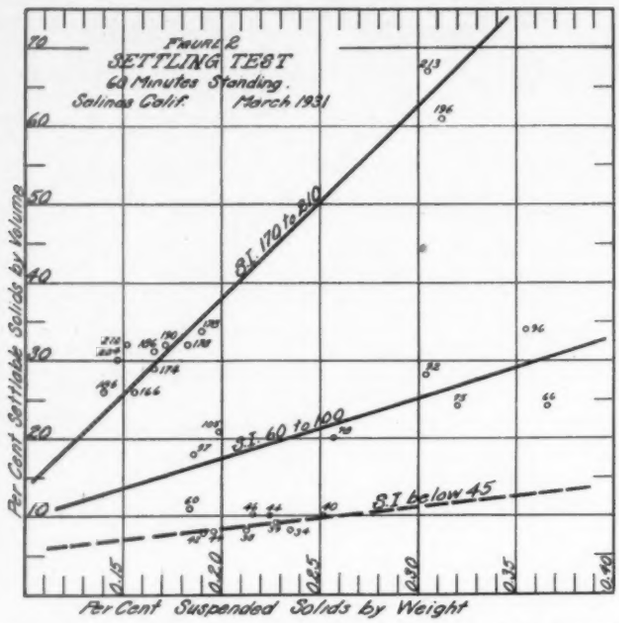


Fig. 2.—A Picture of the Lack of Correlation Between Volumetric Sludge Test and the Gravimetric Test. The Necessity of Taking into Consideration the Density and Settleability (Sludge Index) Is Clearly Evident.

the minimum *weight* of sludge that it is necessary to carry in his own individual plant and then, second, to so control the rate of sludge return that that minimum amount is never greatly exceeded. To solve that problem it would be desirable to have some rapid and accurate means of approximating the *weight* of solids in a given volume of mixed liquor or return activated sludge. As yet no universally satisfactory method of making this determination has been devised. Three methods that have been more or less generally used are (a) settling tests, (b) suspended solids determinations, and (c) centrifugal tests.

All have their disadvantages.

Settling Tests

These are the simplest tests and were the earliest tests used. Samples of sludge or mixed liquor are simply collected in liter graduates, allowed to stand for some given time, and the per cent of settleable solids observed at the end of the given time. In the early days it was usually customary to carry about 20 per cent sludge, after 30 minutes standing, in the mixed liquor. The test is still used and is quite helpful so long as its limitations are kept in mind. Various standing times are used ranging from 10 minutes to 1 hour.

Attempts to correlate the volume of settleable solids, as determined in this way, with the actual weight of the suspended solids in the sample soon showed that no such relationship existed unless the sludge index[9] was also taken into consideration, see Figure 2. "The sludge index (S.I.) is the volume in cubic centimeters occupied by 1 gram of sludge solids after settling 30 minutes." The longer the settling test samples are allowed to stand, i.e., the more the sludge compacts, the less the influence of the S.I. on the results of the test and hence the closer their approximation to the actual weight of sludge solids present. Figure 1 illustrates this point fairly well. However, the rate of sewage inflow to the aeration tanks is constantly changing and tests to regulate the amount of return sludge must be rapid if the weight of sludge solids returned is to be varied in accordance with the sewage flow.

In general the settling test alone can not be relied on except in the smallest plants, and even then only in those small plants that are so amply designed that they are subject to little bulking. In such plants the possible saving in power may not be great enough to warrant the added cost of conducting more accurate test methods.

Suspended Solids Determinations

Suspended solids determinations are the only accurate means of determining the actual *weight* of sludge solids in a given sample of mixed liquor or return sludge. Unfortunately so much time is required for making the determinations that the test is useless as a means of coordinating the hourly rates of addition of sludge solids with the hourly rates of sewage inflow to the aerators. In spite of this handicap the test is extremely valuable and should be made at least once a day at all but the very smallest plants. It should be made at the same time each day; the time selected should be such that the sewage flow for the past several hours has been nearly identical with that of the same hours of each preceding day.

For example, at Salinas[5] we took samples for suspended solids determinations each day at 9 a. m., there being only slight day to day variations in the hourly rates of flow received at that plant between 2 a. m. and 9 a. m. We governed the daily amount of activated sludge wasted almost entirely by the results of these determinations. (The rate of sludge withdrawal from the clarifiers was governed by hourly determinations of the depth of sludge in them. We attempted to keep the rate of withdrawal as low as possible without permitting more than a 1-foot depth of sludge at the sides of the Dorr tanks.) This procedure did *not* accomplish the very desirable end of keeping the suspended solid content of the aerators constant at all times throughout the day. It was probably at a minimum about 11 a. m. when the peak flow started coming in and at a maximum between 10 and 11 p. m. when the flow started dropping off rapidly. However, it did serve to keep the *average daily* suspended solid content of the aerators fairly constant.

Before leaving the subject of gravimetric solids determinations the writer wishes to make a plea for all operators to base their control on *suspended* solids determinations rather than on *total* solids determinations. It is the suspended solids in the sludge that exert the bulk of its oxygen demand. It would be permissible to base plant control on total solids determinations only if the dissolved solids were practically constant. Such is not the case—at Salinas,[5] dissolved solids in the mixed liquor, and plant effluent, ranged from 600 to 1500 p.p.m. under varying sludge conditions.

Centrifugal Tests

This test consists of collecting samples of mixed liquor or sludge in 15 m.l. centrifuge tubes and "spinning" them for a given short time (2 to 5 minutes) in an electrical centrifuge. A hand centrifuge will not serve because of the impossibility of always spinning the samples at the same speed. The writer first heard of this test being used at the Indianapolis plant some eight or nine years ago. We tried it for several months at Salinas. Mr. Anderson[2, 3, 4] has recently reported its successful use at Rockville Center. The test has probably been used at several other plants but it has never been widely adopted. To the writer's knowledge, Mr. Anderson is the first to mention it in the literature.

Like the settling test, the centrifugal test is at best volumetric determination. Nevertheless, it has two outstanding advantages over the gravity settling test. (a) It is extremely rapid and so

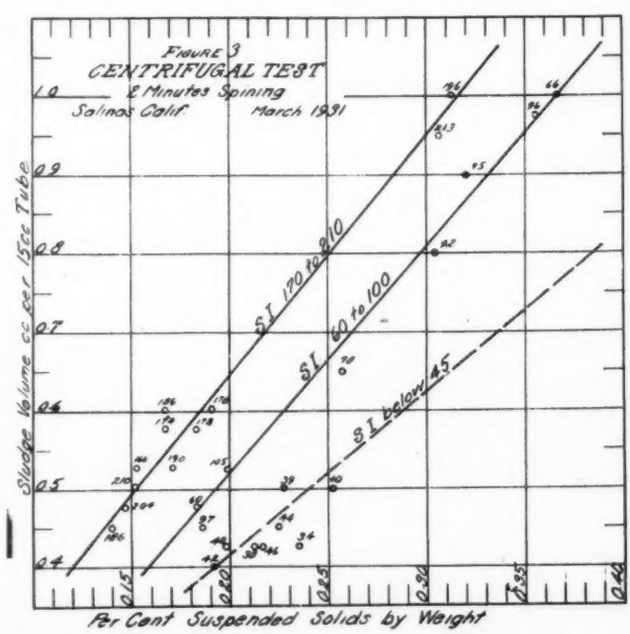


Fig. 3.—A Picture of the Less but Evident Effect of Sludge Index Values on Suspended Solids Tests With the Centrifuge.

may be utilized, with reservations, to control the hourly rates of sludge withdrawal or return. (b) It compacts the suspended solids more and hence there is better correlation between its results and those of gravimetric suspended solids determinations. However, even the results of this test are greatly influenced by the sludge index as is clearly shown by Figure 3. If that fact is not fully appreciated the operator may encounter serious complications in attempts to regulate *weight* of suspended solids in his aerators.

If the test is to be used the operator should first make sufficient trials to prepare a graph similar to Figure 3. Once such a graph is available he may determine the sludge index once a day and from that determination and the graph he can select the desirable centrifugal test results for the more frequent determinations made on the mixed liquor, return sludge, etc.

To substantiate this assumption we submit Table I. Sample 6 was a sample of the return sludge from the Salinas plant; samples 1 to 5, inclusive, were prepared by diluting sample 6 with varying amounts of final effluent that had been collected at the same time.

TABLE I

Sample	Suspended Solids % by weight "A"	Settleable Solids % by volume 30 min. standing "B"	Sludge Index (B/A)
1.....	0.064	5	78.1
2.....	0.172	15	87.2
3.....	0.289	25	87.2
4.....	0.400	35	87.5
5.....	0.549	50	91.1
6.....	1.078	100	92.8

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(9) F. W. Mohlman, "The Sludge Index."—Sewage Works Jour., 6, 119 (January, 1934).

Standards of Practice—The Indianapolis Water Co., Indianapolis, Ind., keeps a code-book which outlines procedure in all kinds of situations, even to specifying the kind and color of paint to be used in various places. The "code" could never be complete because of changes from time to time, as conditions warranted. However, it served as a valuable guide and a record of previous decisions.

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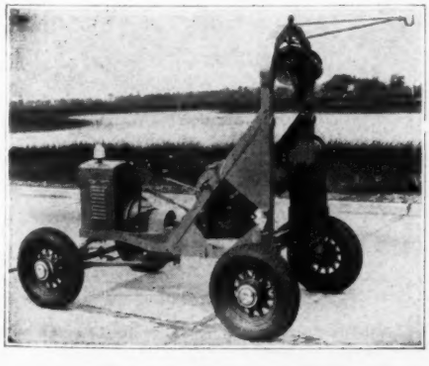

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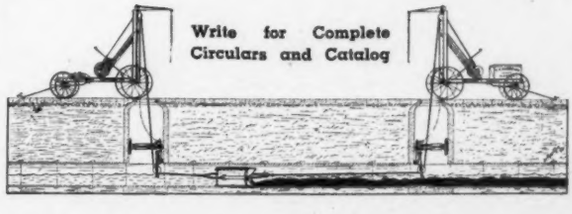


SLUDGE BLANKET DETECTOR AND TURBIDIMETER

By DON E. BLOODGOOD

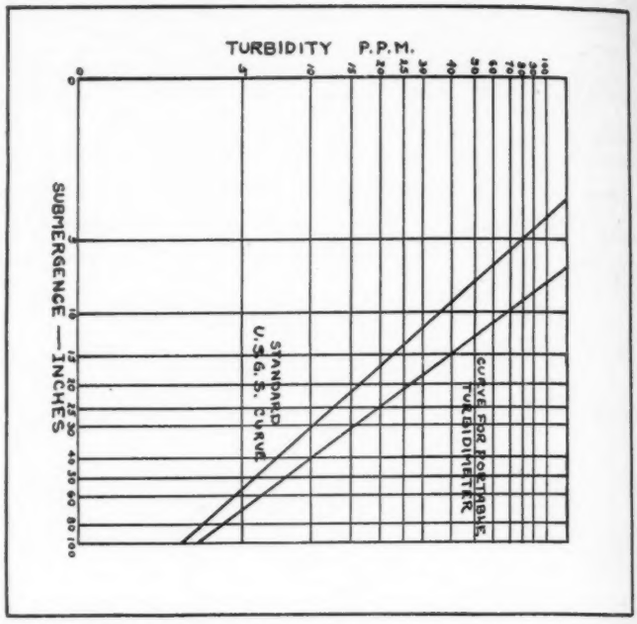
Engineer, Sanitation Plant, Indianapolis. Ind.

To a sewage plant operator, the appearance of the effluent is the best indication of the effectiveness of the treatment process. But to convey to the superintendent an accurate description of the appearance, in writing, is difficult. A superintendent should know each morning the hourly condition of his plant during his absence. He also wants his operators to be able to tell him how one day's effluent compares with that of any other day.

To supply this information in the most concise, yet explicit form, an instrument has been constructed at the Indianapolis Sewage Treatment Works which can be used as a portable turbidimeter and a sludge blanket detector. It consists of an 1¼ inch I.D., 0.065 wall, 2 FH aluminum tube 68 inches long with a sleeved brass collar on the bottom into which the brass moisture proof lamp case screws. There are four ports in the cap which admit water but exclude all outside light. The glass disk is held against a rubber gasket making a water tight joint. In the 1/32 inch metal disk there is cut a ¾ inch cross of 0.012 inch opening with the center closed off by a piece of metal not larger than 3/32 inches in diameter to blank out the bright spot caused by the bulb filament. The light reflector is painted with aluminum paint. The operation of the lamp is identical with the ordinary two cell flashlight except for the self-operating mercury switch. This mercury switch is in the base cap of the lamp case and is constructed in a case of sealing wax. The sealing wax was first run into the base cap and sloped to a small depression in the center. A short piece of No. 24 platinum wire was set on each of opposite sides of the depression with the ends about ⅛th of an inch apart. One wire is grounded to the base cap and the other is connected to a copper plate, making a connection with the battery through the coil spring. Only a very small drop of mercury is needed in the switch. After the mercury is placed, a heavy paper disk is set over the top of the mercury pocket and the cap is filled with sealing wax.

In use, the instrument is submerged to a point at which the cross disappears and then the scale on the side of the tube is read by looking in to the six-sided mirror of the float, in one plane of which the figures will show. The mirrors are set at a 45° angle with water proof china cement in sycamore or any other tough light wood.

The portable turbidimeter was calibrated by getting the submergence in effluents of known turbidity. This data when plotted on logarithmic paper gave a curve somewhat different than did the data of the standard U.S.G.S. turbidity table, as can be seen by the accompanying graph. The scale for any turbidimeter constructed could be obtained from the graph of the calibration data



Graph for Converting Submergence Into Trubidity Reading

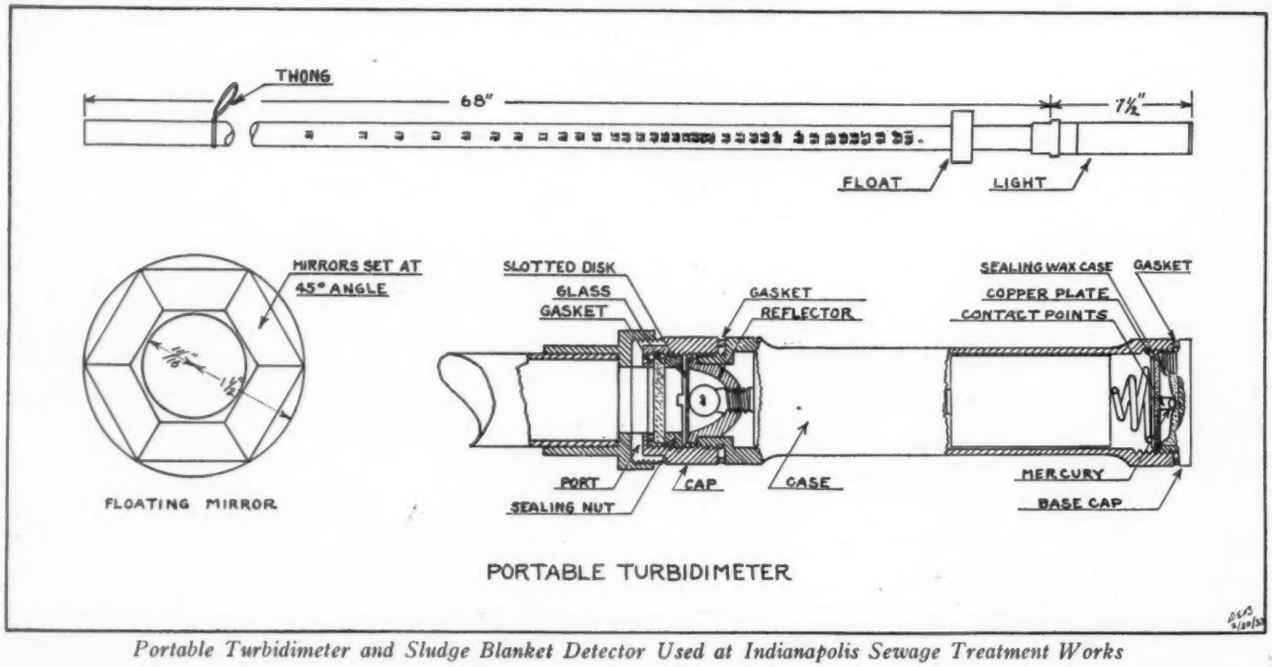
or it could be calculated by developing a formula for the particular curve, similar to the formula of the standard curve:

$$\log y = -1.106598 \log X + 2.6570$$

in which y= p.p.m. of turbidity and X = submergence in inches. The curve for the portable turbidimeter herein described is:

$$\log y = -1.35652 \log X + 3.2085$$

The shortcomings of the portable turbidimeter are appreciated. The turbidity increases at lower levels of the basin so that the readings obtained may not describe the nature of the actual effluent and yet be indicative of plant operation. At Indianapolis, however, the information obtained through the use of the portable immersion turbidimeter has been very helpful in connection with plant operation.



Portable Turbidimeter and Sludge Blanket Detector Used at Indianapolis Sewage Treatment Works

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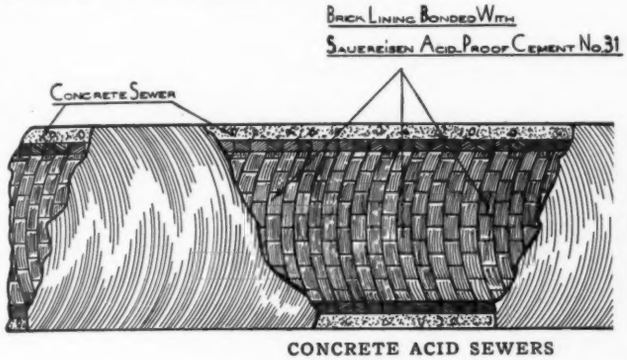

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This is a modern, quick-setting, self-hardening cement, which can be mixed on the job as it is being used, in correct, specified proportions, thus eliminating all hazards of careless mixing.

It is highly resistant to all acids encountered in sewer use, and is proof against solvents, chlorine, bromine, etc.

It makes a water-proof joint, there being no expansion or contraction in the hardened cement joint.

SAUEREISEN No. 31 is shipped as a white powder, with sufficient liquid binder to make a smooth, creamy paste, as used. These two parts are shipped as a unit. For best results, use 70% Filler with 30% Binder, stirring slowly and mixing thoroughly.

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SAUEREISEN No. 48 is a melting compound with sulphur as its base, combined with other ingredients to melt and pour easily. It is high in tensile and compression strength, adheres ideally to brick or tile and resists water, acid, oil, etc.

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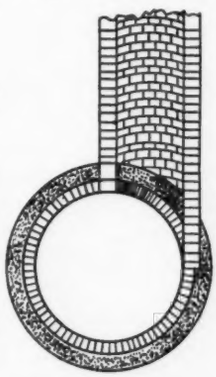

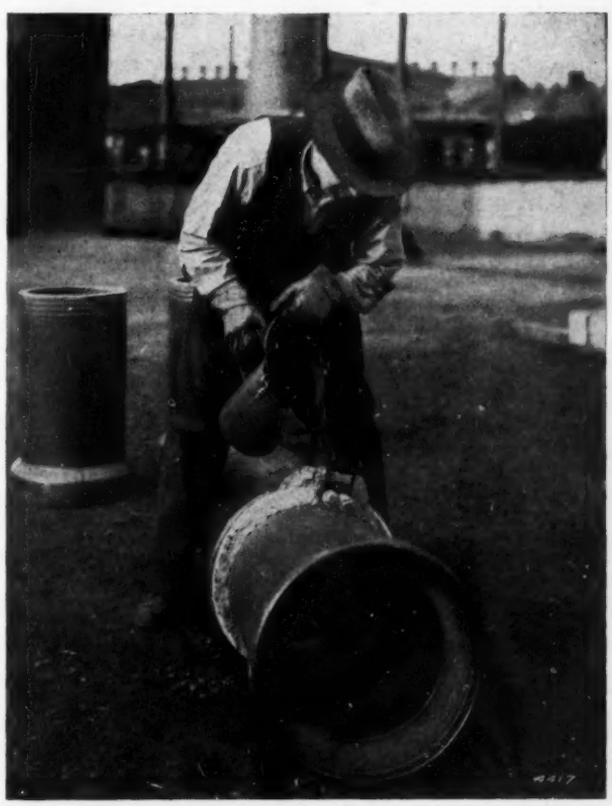

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THE job of jointing sewer pipes has been done for many years. Engineers have specified materials for the job, contractors have bought materials, workmen have applied the materials. The jobs have been done—but many were not well done. Although progress has been made from time to time the perfect job to be desired in a sewer joint is the one which is *long-lived, water-tight, flexible, root-proof, and resistant to acids.*

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I. EASE OF INSTALLATION. The job of installing Pre-moulded Belt is extremely simple. A workman knows in advance what to expect. He picks up a section of required size and shape, places it, and drives it home—the job is done neatly—quickly—properly, with no excuse for puttering around.

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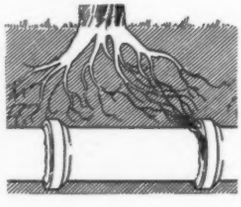
III. ROOT-PROOF. The fibrated asphalt belt entirely filling the joint prevents entrance of capillary and large roots.



IV. EASE OF INSPECTION.—CAMOUFLAGE PROOF—FALSE APPEARANCE PROOF. An inspector can see from the top of the trench that the joint is properly calked. If more than a hump is visible, the belt needs more calking. This is an important factor because it has to do with the fallibility of workmen. Joints with other materials are too easily camouflaged. Without a close checkup you never know if the annular space is actually and properly filled.

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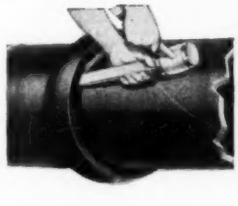
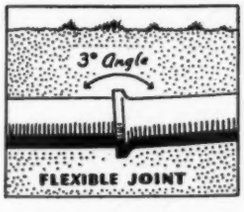


VI. FLEXIBILITY. Pre-moulded Belt Joints adjust themselves to ordinary trench settlement and ground movements. This is due to the nature of asphalt and the tensile strength added by the fibrous component material. *There is reasoning* and a long period of laboratory and "On the Job" testing behind this product.



VII. RESISTANCE TO ACIDS. The specially prepared bitumens make Pre-moulded Belt impervious to the action of sewer liquors and acid resisting.

VIII. ORDER EXACT AMOUNT. The length of installation known, number of sections and joints known, the contractor can order the exact amount and exact size of material. There is no guessing, no experience in buying required. No over supply to be stored. No insufficiency due to wasteful use. This factor often makes a great material saving.

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Sewers require repair when broken from ground movement. A movement of one inch in one section of a line should be taken up by the flexible joint compound. Tufflex is guaranteed to have this flexibility. Foreign matter such as soil or roots often work into joints and cause a stoppage of the flow. Tufflex also is made with a root-deterrent and being cohesive as well as adhesive does not allow soil to infiltrate.

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HARDENS UNDER WATER

Servitite comes in units of 128 pounds of which 100 pounds is in powder form and 28 pounds in liquid form. These proportions are arrived at so that any number of mixings will use up the unit.

The root of all (or most) evil to sewer pipes is the growth of tree roots through faulty joints. Although a metal might repel a root due to hardness, the materials used for sewer pipe joints are not of that nature. Therefore, the only way to stop root growth is to introduce an ingredient in the material which will stop root growth. Recommended by the Clay Pipe Association as a necessary improvement Servicised Products Corporation prepares all "Servitite" in this manner.

To make a tight joint a material should be used that will permit no doubt of the joint being full and the pipe centered in an equal amount of joint material on all sides. Also, the material should be one which will not wash away. Many types of material give a false appearance indicating that the joint is full whereas much of the material has run down into the pipe leaving a hollow space in the material which is easily broken down when trench settlement takes place. Servitite plastic cannot run or crumble away. Servitite fills every joint tightly adhesive to the pipe for a long life.

We also make hot asphalt pouring compounds.

Write for our catalog—Non Extruding Expansion Joints.

ACTIVATED SLUDGE THICKENING*

By D. TRAVAINI

Superintendent, Sewage Treatment Works, Phoenix, Ariz.

Phoenix, Arizona, has an activated sludge plant with Dorrco aerators, and utilizes separate digestion of mixed crude sludge solids and the wasted activated sludge. C. C. Kennedy, Consulting Engineer, who designed the plant, provided a sludge thickener for the purpose of concentrating activated sludge.

The sludge thickener, as constructed, is a circular tank 35 ft. in diameter with an effective depth of 9 ft. at the periphery of the tank with 1 ft. of free board above the water level. The thickening mechanism was supplied by the Dorr Company and consists of a picket fence made of 2-in. pipe on 6-in. centers extending 5 ft. above the bottom of the tank floor. This is attached to the bracing supporting the bottom scrapers. A skimming arm is also provided. See Fig. 1.

The tank is centrally located and arranged so that waste activated sludge, mixed liquor, plant effluent, primary sludge, or digester overflow liquor can be admitted through pipe inlets at one side of the tank, approximately 18 ins. below the water level.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, April 1934.

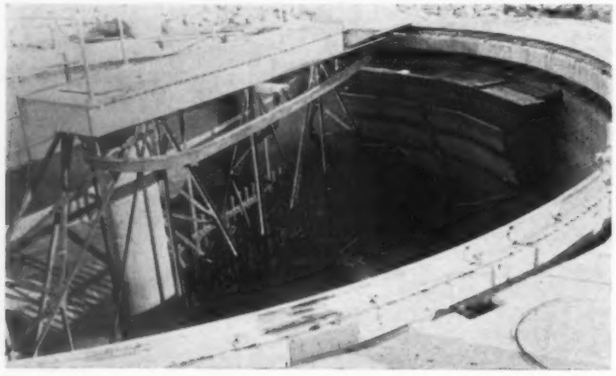

Fig. 1—Thickener Mechanism Showing Picket Fence Bottom Scrapers and the Sacramento Type Inlet Baffle

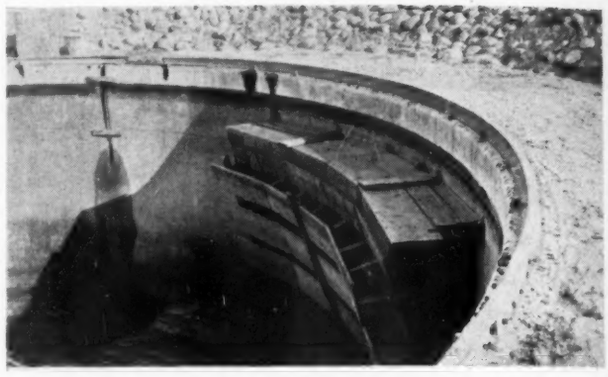

Fig. 2—Sacramento Baffle and One of the Three Chlorine Hose Inlets

A 24-in. redwood baffle 13 ft. long was provided in front of the pipe inlets.

The original baffle at the inlet was not satisfactory. Short circuiting was so pronounced that it prevented effective utilization of the tank capacity. After considerable investigation, a Sacramento baffle was installed in May, 1933, and ended the short circuiting troubles. We attribute the successful use of the thickener to this baffle and the installation of a Wallace and Tiernan chlorinator made at the same time, the value of which will be discussed later. Before these improvements were made we were prone to look upon the thickener as a liability rather than an asset.

The Sacramento type baffle was developed under the direction of Professor Charles Gilman Hyde more than ten years ago. The structure built at Phoenix consists of a redwood baffle 24 ins. from the wall at the water surface, tapering to 9 ins. at the wall 36 ins. above the intersection of the vertical wall and sloping bottom. This baffle is perforated with 4-in. square openings on 18-in. centers, both ways. Nine inches in front of these openings

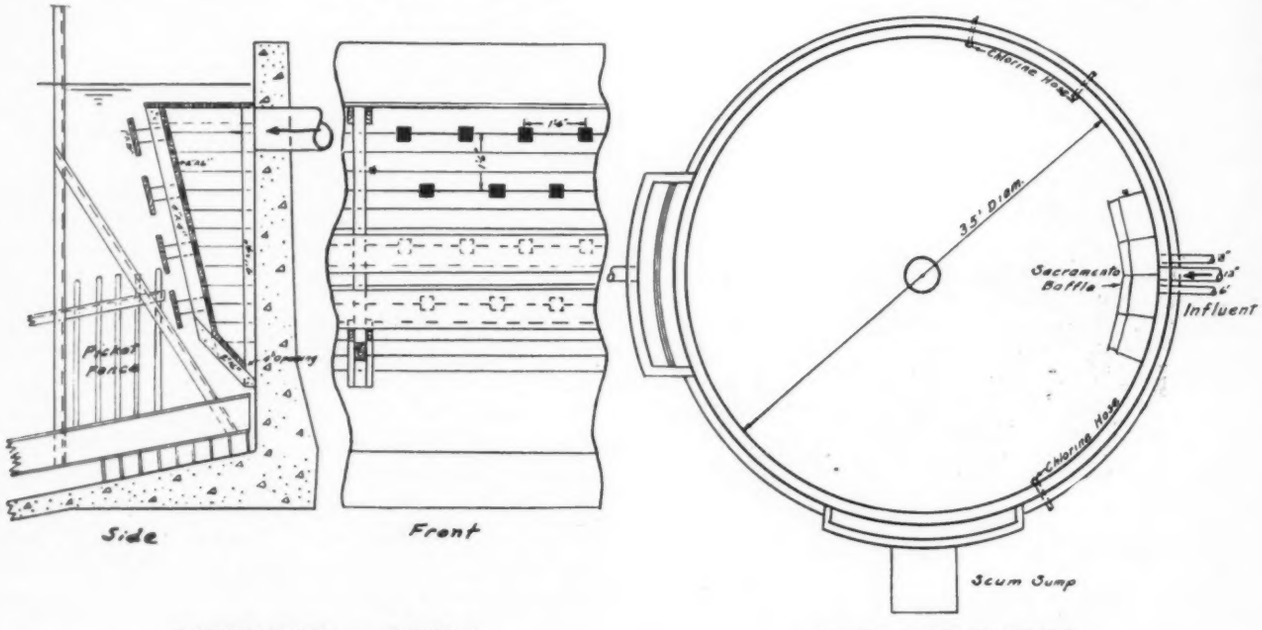

Fig. 3—Detail of Sacramento Baffle and Plan of Thickener, Showing Location of Baffle and Points of Chlorine Application

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
Dry Chemical Feed Devices, etc.
NEWARK, NEW JERSEY

"The Only Safe Water Is a Sterilized Water"

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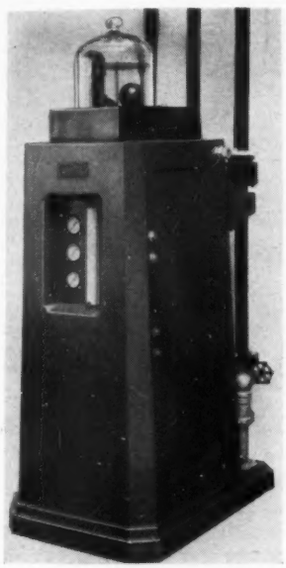
CHLORINATION OF SEWAGE

Of all chemicals used in sewage treatment, chlorine has by far the widest application. From simple disinfection to use as an adjunct to the most involved treatment process, chlorination has for many years been the versatile and valued aid of the man concerned with sewage disposal.

Chlorination is employed to stabilize raw sewage, control odors along trunk sewers or at treatment plants, protect masonry structures from disintegration, increase efficiency of filter beds and prevent filter ponding, improve sedimentation and removal of settleable solids, improve sludge digestion, prevent bulking in activated sludge plants, reduce biochemical oxygen demand and retard putrefaction in the receiving water course, disinfect effluents before discharge and as a necessary adjunct to nearly any process of chemical precipitation.

DISINFECTION

Regardless of what the preliminary process of sewage treatment may be, disinfection of the effluent before discharge has come to be regarded as a necessity. Protection of water supplies, of bathing places and of shellfish propagation beds all require efficient disinfection. That chlorination offers the one practical and effective means of sewage disinfection today is universally acknowledged by sanitarians and public health authorities.



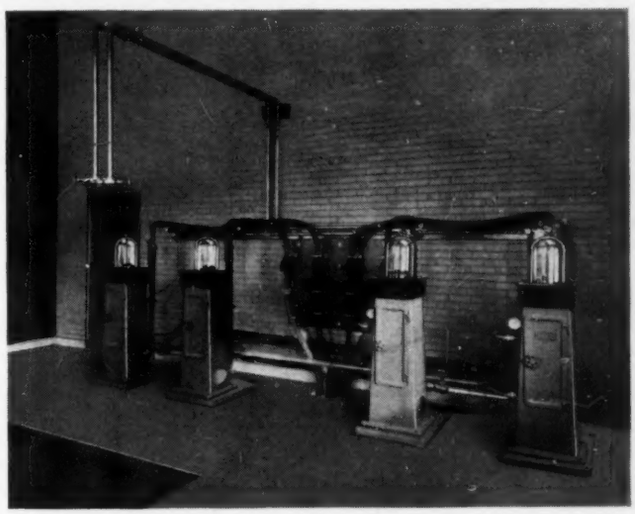
Master Visible Vacuum Chlorinator — W&T Visible Vacuum Control is now available in equipments ranging in capacity from .03 to 2000 pounds of chlorine per 24 hours.

ODOR CONTROL

Control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulphide (the gas responsible for these obnoxious odors) or prevention of its formation by controlled application of chlorine, is not only practical but also satisfactory in results and economy of operation.

B. O. D. REDUCTION

In order to prevent production of odor nuisance, foul appearance and death to fish life in streams receiving the effluents from sewage disposal plants, chlorination for B. O. D. reduction has become increasingly popular. Offering, as it does, a simple, easily controlled and relatively inexpensive means of supplementing other purification processes during periods of low stream flow or for permanent use at a plant where the dilution factor is low, chlorination has, in many cases, eliminated the necessity for extensive additions to the regular treatment works.



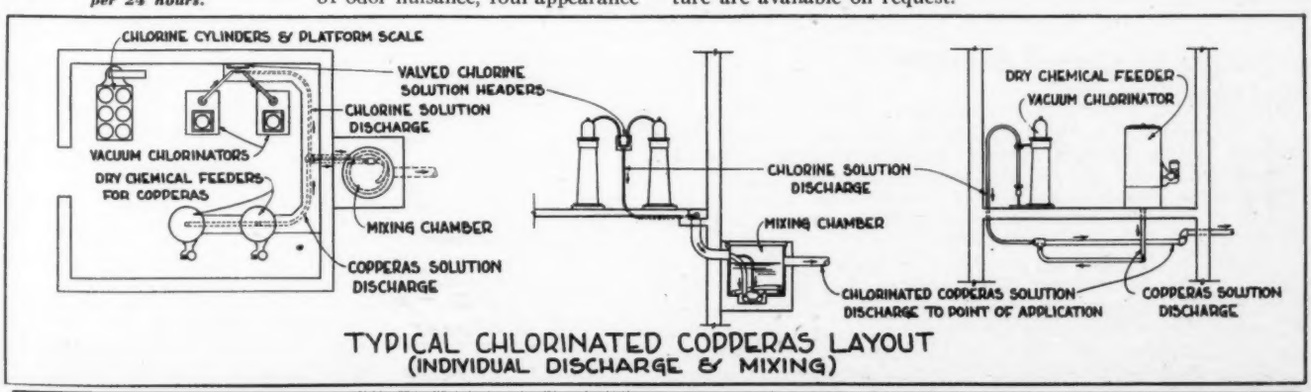
Installation of four Visible Vacuum Chlorinators at the New Haven, Conn., Sewage Disposal Plant.

IRON SALTS IN SEWAGE TREATMENT

Lowered cost of chemicals and other contributing factors have greatly increased the popularity of iron salts for various uses in sewage treatment, odor control, sludge conditioning, chemical precipitation, etc.

In whatever form this treatment may be adopted, such as the manufacture of ferric chloride at plant site, the addition of ferric chloride or of ferric sulphate directly, or the use of chlorinated copperas, W&T are prepared to furnished the necessary equipment. Complete details on request.

W&T field representatives will gladly confer with you about any specific problem relating to the application of chlorine or iron salts in sewage treatment. Technical publications and literature are available on request.



TYPICAL CHLORINATED COPPERAS LAYOUT
(INDIVIDUAL DISCHARGE & MIXING)

TABLE 1—RETURNED SLUDGE AND MIXED-LIQUOR (SLUDGE) THICKENING DATA. (RESULTS REPRESENT 24-HR. COMPOSITE SAMPLING.)

Date	Gals. of mixed liquor wasted	Chlorine #/24 hrs.	Influent (Mixed Liquor) pH	Influent (Mixed Liquor) % by volume 1 hr. settling	Influent (Mixed Liquor) Suspended Solids p.p.m.	Influent (Mixed Liquor) Suspended Solids % dry wt.	Effluent Total Solids p.p.m.	Effluent Suspended Solids p.p.m.	Effluent B.O.D. p.p.m.	Effluent pH	Thickened Sludge % Solids dry weight	Thickened Sludge pH
1/18/34	144000	35	7.6	30	1620	0.162	1075	21	20	7.6	—	—
1/19/34	144000	35	7.6	42	1725	0.172	1007	31	26	7.6	4.021	7.6
1/20/34	132000	35	7.8	50	1823	0.182	1012	31	28	7.8	4.287	7.8
1/21/34	144000	35	7.8	55	1342	0.134	1000	16	38	7.8	3.937	7.8
1/22/34	132000	30	7.6	50	1865	0.186	938	42	36	7.6	3.571	7.8
1/23/34	234000	45	7.6	47	2339	0.234	1020	26	26	7.6	4.120	7.6
1/24/34	288000	63	7.6	42	1618	0.162	1074	37	46	7.6	4.090	7.6
1/25/34	207000	50	7.6	54	2232	0.223	1015	26	32	7.6	3.529	7.6
1/26/34	132000	50	7.6	40	1065	0.106	1045	13	16	7.6	3.996	7.6
1/27/34	172000	41	7.6	32	1255	0.125	909	38	30	7.6	3.827	7.6
1/28/34	158400	40	7.6	30	1863	0.186	1010	27	22	7.6	4.090	7.6
1/29/34	158400	36	7.8	28	1652	0.165	995	13	16	7.8	3.684	7.8

Date	Gals. of returned act. sludge wasted	Chlorine #/24 hrs.	Influent (Returned Activated Sldg.) pH	Influent (Returned Activated Sldg.) % by volume 1 hr. settling	Influent (Returned Activated Sldg.) Suspended Solids p.p.m.	Influent (Returned Activated Sldg.) Suspended Solids % dry wt.	Effluent Total Solids p.p.m.	Effluent Suspended Solids p.p.m.	Effluent B.O.D. p.p.m.	Effluent pH	Thickened Sludge % Solids dry weight	Thickened Sludge pH
2/9/34	70500	60	7.6	98	5243	0.524	1210	36	106	7.6	—	—
2/10/34	60300	65	7.8	88	5651	0.565	1163	43	126	7.8	3.618	7.8
2/11/34	45200	65	7.8	99	6920	0.692	1090	28	95	7.8	3.684	7.8
2/12/34	38500	55	7.8	99	7848	0.785	1215	45	152	7.8	3.262	7.8
2/13/34	54100	65	7.8	98	8132	0.813	1230	52	166	7.8	4.127	7.8
2/14/34	19200	50	8.0	98	7337	0.734	1140	38	120	8.0	4.006	8.0
2/15/34	30300	55	7.8	98	8243	0.824	1125	45	138	7.8	3.529	7.8
2/16/34	11040	40	7.8	98	9130	0.9130	1110	32	95	7.8	3.280	7.8

Note:- Results from 24 hr. composites.

are suspended wooden baffle boards 10 ins. wide. See Figs. 2 and 3.

Operation of Thickener

Since the plant was first placed in service on March 15, 1932, the thickener operation has been diversified. We have used this structure to concentrate primary sludge, wasted activated sludge, combined primary sludge and wasted activated sludge, waste mixed liquor, combined primary sludge and waste mixed liquor, and digester overflow. The results obtained varied considerably and with some of the operations odor nuisance became a serious problem. The use of the thickener was, for the time being, abandoned.

On June 2, 1932, activated sludge had built to a point where wasting could proceed, and the thickener was again placed in service. We were unable, however, to hold the sludge in the thickener sufficiently long to obtain the degree of concentration anticipated when the tank was designed. When we attempted to hold it to increase the solid content to the point anticipated, the sludge would rise and odors became pronounced.

Attempts to Control Septicity and Short Circuiting

In the early part of October, 1932, we arranged to return plant effluent to the thickener, hoping that the dissolved oxygen in the effluent would retard septic action and thus eliminate odors and allow a longer sludge holding period. This procedure aggravated the short circuiting in the tank and caused the solids in the effluent to increase materially.

The short circuiting in the thickener made it apparent that the original baffle was not efficient and resulted in the installation of the Sacramento baffle. We also installed a Wallace and Tiernan solution feed chlorinator in order to use liquid chlorine to retard septic action. With the chlorinator we anticipated accurate control of chlorine applied to the thickener, which was not

TABLE 2—SLUDGE CONCENTRATION DATA

	Depth from liquid level in ft.	Nov. 3 1933	Dec. 11 1933	Jan. 20 1934	Feb. 11 1934
% Solids in sludge at depth shown	3	—	0.25	0.27	0.810
	4	0.50	0.50	0.70	1.02
	5	1.20	1.05	1.45	1.35
	6	1.04	1.25	1.37	1.72
	7	1.20	1.40	1.55	2.38
	8	1.40	1.70	2.10	2.87
	9	3.50	3.25	3.75	3.05
	Cone.	4.08	4.21	4.28	3.68
% Solids in Sludge—Influent		0.105	0.175	0.182	0.692
pH - Influent		7.8	7.8	7.8	7.8
pH - Thickened Sludge.		7.6	7.8	7.8	7.8
Suspended Solids p.p.m. - Effluent		20	25	31	28
B.O.D. - p.p.m. Effluent		—	30	28	95

Note:- Results from 24 hr. composites.

L. A. WESTON

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MANUFACTURERS OF

WESTON'S GASKET and FORM FOR BELL and SPIGOT SEWER PIPE JOINTS (Vitrified or Concrete)

Weston's Gasket and Form for Bell and Spigot Pipe. Made of sheet metal. Gasket takes the place of jute, and automatically aligns spigot in bell, insuring an even annular space and definite depth remaining in socket for cement mortar. Also produces even flow line at the invert.

Form encloses lower half of joint to a point slightly above spring line. Form is filled with cement grout. Upper portion completed by hand, using a dryer mix.

The Weston Gasket and Form permits the making of cement joints in trenches containing ground water, as latter can be drained through the pipe as it is being laid.

Furnished in sizes up to and including 24".

Photograph shows line of 8" pipe with gasket and form attached, ready for pouring of cement grout.

WESTON'S FORM FOR TONGUE and GROOVE CONCRETE SEWER PIPE JOINTS

Weston's Form for Tongue and Groove Concrete Pipe. Made of sheet metal. Encloses three-quarters of circumference of the joint. When filled with cement, grout forms a collar of concrete 3" wide by 1¼" in thickness. The top quarter portion of the joint is then completed by hand, with a collar of cement mortar of same dimensions.

Note: The inside of joint to be pointed up with mortar before filling form with grout.

Furnished for all sizes of pipe.

Photograph shows 42" line of tongue and groove concrete pipe with Weston Form attached. Note back fill to spring line before grout has been introduced into the forms.

Both of above photographs show a part of the installation of the Arlington County (Virginia) Sanitary Sewerage System, where over 100 miles of sewers from 8" to 42" in diameter were laid in 1935.

All lines were tested for infiltration with a minimum of 4' head of water above same. Maximum infiltration allowance was 10,000 gallons per mile per day (24 hours).

Average infiltration (computed) was approximately 2,500 gallons per mile per day.

In view of the rigid infiltration test, Weston's Gasket and Form for Bell and Spigot Joints, and Weston's Form for Tongue and Groove Pipe Joints were used throughout by choice of the Contractors.

possible under the crude conditions in which we had been using lime and chloride of lime earlier.

We devoted our spare time to experiment, to determine the efficiency of the baffle and to find at which points to chlorinate the sludge input in order to obtain the best distribution of chlorine. The results obtained from the baffle were very gratifying. By the trial and error method we selected three points of application of chlorine that gave the best distribution. The chlorine hoses are submerged 3 ft. below the liquid level in the tank. One point of application is 13 ft. along the periphery of the tank from the west end of the baffle. The other two points are 9 ft. and 18 ft., respectively, along the periphery of the tank from the east end of the baffle.—See Figs. 2 and 3.

By varying the quantity of chlorine solution applied at the points mentioned even distribution of chlorine was maintained in the surface liquor, where desired, rather than in the sludge proper.

With this preliminary work completed, during the early summer we tried concentrating primary sludge in combination with mixed liquor taken from the aeration tanks; then primary sludge with returned activated sludge, and then returned activated sludge alone. Very good results were obtained in each instance, but the trials with mixed-liquor seemed the best.

The Scheme That Gave the Best Overall Results

In August, 1933, we decided to try concentrating mixed liquor only, a method suggested by R. F. Goudey.[1]

Our object was, that in summer the primary clarifier influent is stale and we felt that by adding to the crude sewage a sizeable flow of effluent from the thickener, containing dissolved oxygen and some residual chlorine, it would improve plant operating conditions. The amount of thickener effluent would naturally be much greater when concentrating sludge from mixed liquor than when concentrating returned activated sludge and therefore the greater benefit to the crude sewage.

The results obtained by thickening mixed liquor taken from the aeration tanks were so satisfactory that we soon adopted it as routine operation. The primary sludge is concentrated to approximately 5 per cent in the primary clarifier and is mixed with the thickener sludge by pumping sludges from both tanks simultaneously to the digesters.

In Table No. 1 analytical data of thickener operations are given for mixed liquor and also when "returned" activated sludge from the clarifier was treated. Table 2 shows the solids content of the sludge at various depths. As a result the installation of the Sacramento baffle and chlorination, we can maintain a clear overflow with the sludge blanket within 3 ft. of the liquid level, when wasting 200 gpm. or less of mixed liquor or returned sludge through the thickener. The costly chlorination is considered very nominal considering its advantages.

Conclusions

Since we installed the Sacramento baffle and eliminated short circuiting, and since we started to chlorinate the top liquor to retard bacterial action and thereby control septicity, the thickener has operated satisfactorily and accomplishes the purpose for which it was designed, viz.: reducing the volume of sludge and hence the volume of supernatant liquor which is so disastrous to the activated sludge process. Likewise the need for greater digester capacity.

[1]"A New Method of Concentrating Activated Sludge," R. F. Goudey and S. M. Bennett. WATERWORKS AND SEWERAGE, May, 1933.

"Dry Cleaning" Air Diffuser Plates

By A. M. RAWN

Associate Editor, Los Angeles, Calif.

Every once in a while someone does something that makes one stop and wonder why it has never been done before. Or, if ever done, why he has not heard of it.

Maybe you have been in Southern California when, due to "unusual weather conditions" the winter temperature drops below freezing and the citrus growers start the orchard smudge-pots, to warm up the whole outdoors and keep the crops from freezing. If you have, you may recollect that upon such occasions the air in the orchard areas is so filled with thick, oily smoke that one cannot see a hundred feet. This winter has been such a one and for a number of days early this month (January) millions of gallons of oil have been burned in the smudge-pots.

Now this may not seem to have anything to do with sewage disposal, but strangely enough it does have.

The city of Ontario lies right in the heart of the citrus grove area and, in consequence, was encompassed in a dense smoke fog for some time. During this period the operator of the Ontario activated sludge plant noticed that the pressure on the air lines was steadily increasing at the blowers. Attributing it to the oily carbon in the air, as most likely responsible for the clogging of the diffuser plates, he made every effort to cleanse the air by straining it through several thicknesses of cloth over the air inlet to the blowers. The cloths were changed frequently but to no avail. And, pressures at the blower mounted from 5 to 7½ pounds over night.

Obviously the diffuser plates, which had operated for more than a year with no building up of pressure, had to be cleaned. The finely divided carbon and oil in the smoke had doubtless spread quite uniformly through the plate pores. The orthodox manner of cleaning would have been to remove the plates and clean them up with a solvent and, if not successful, burn out the volatile materials, possibly. The city engineer had other ideas, however, and instead of bringing the plates to the solvent the solvent was taken to the plates. A scheme for injecting the solvent into the air stream from the blowers was put into operation.

What was actually done was to slowly pump "Aviation" grade of gasoline into the air line and beyond the blower. Two gallons of gasoline was fed into the pipe slowly during a 24-hour period. It did the job all right, because during this period pressures dropped back to normal and the trouble was completly cured. So far, there has been no injurious effect upon the quality of the plant effluent or the behavior of the sludge.

This struck the writer as being a most unique method of overcoming a serious difficulty. Mr. Austin Burt, Ontario's city engineer, was "the brains" behind this "solvent-solved situation"; and H. M. Ely, as chief operator of the plant, was "the brawn."

In his latest advice to the writer the "inventor" of diffuser dry cleaning states: "We have had to apply our gasoline remedy to the diffuser plates *seven* different times during the more than two weeks of smudge conditions. Each time the pressure was brought back to normal, and thus far we have been unable to detect any serious consequences in the operation of the plant. Altogether, we used seven and one-half gallons of aviation gasoline at the total cost of only $1.16 and feel pretty good at saving the trouble and cost of emptying the tanks, removing and cleaning the plates."

SERVICING OF POROUS AIR DIFFUSERS*

By FRANK C. ROE

Sanitary Engineer, The Carborundum Co. Niagara Falls, N. Y.

To maintain the high efficiency of porous diffuser plates and tubes of the type used for aeration in sewage and water treatment plants, their operation should be checked regularly. Partial clogging of the porous structure may occur for a number of reasons, thereby decreasing the effectiveness and increasing the cost of aeration.

The writer and his company have made a study of the various methods of servicing diffusers necessary to maintain their efficiency for a reasonable life.

The most immediate and positive indication of obstruction within the diffuser structure is an increase of compressor or blower pressure necessary to supply a given quantity of air. Visual examination of the aeration tank or tanks will also disclose non-uniformity of diffusion which may be due to a partially clogged condition. This is a practical determination but not so conclusive as the first.

Diffusers may become clogged on either the air side or on the liquor side; that is, on the top or bottom of plates and on the outside or inside of tubes. Both classes of clogging may be experienced simultaneously, but are avoidable to a great extent.

Liquor Side Clogging

1. *Suspended Solids*: Perhaps the most common type of clogging is caused by interruption of aeration during which the solids in water, sewage, sludge or mixed liquor settle and the water content filters through the diffusers into the air duct. Most of the solids in suspension are intercepted at the diffuser surface, but a definite proportion, depending on the pore size, will enter the top 1/16 to ⅛ inch of the structure. When aeration is resumed all of these particles will not be blown out of the structure and cumulative clogging results.

Maintenance of continuous air delivery, at least to some degree, is the positive way to preclude this trouble. Temporary cessation of the air supply is not impossible with modern equipment, but the usual auxiliary blowers with standby power units and inexpensive automatic control equipment will largely eliminate shutdowns.

Care should also be taken not to over-design in the matter of diffuser area. Not less than one cubic foot of air per minute should normally be discharged per square foot of diffuser area. Insuring a higher rate, so as to maintain good air velocity through the pores as well as uniformity of diffusion from the entire diffuser area, is better practice still.

2. *Organic Growth*: Another form of liquor side clogging is growth of bacterial and protozoa life in the uppermost portion of the porous structure. This may be attributed, at least partially, to non-uniformity of diffusion. All of the diffusers controlled by a single valve may not have similar permeability ratings, or the individual areas of any particular diffuser plate or tube may not be uniform one with another.

As suggested, it should be possible to avert clogging of this nature by careful installation and selection of plates or tubes. All units controlled by a single air valve should have a similar permeability rating within limits of 0.5 cu. ft. or less. Uniformity of individual diffusers depends upon precision and perfection in manufacturing.

*Excerpts from an article appearing in WATER WORKS AND SEWERAGE, April 1934.

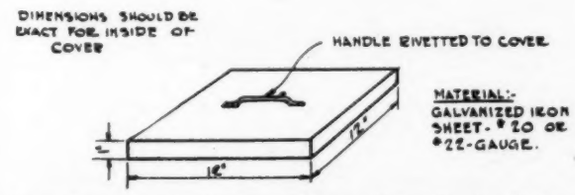

DIMENSIONS SHOULD BE EXACT FOR INSIDE OF COVER
HANDLE RIVETTED TO COVER
MATERIAL:- GALVANIZED IRON SHEET- #20 OR #22-GAUGE.
12"
16"

Plate Cover for Protecting Diffuser Plates During Setting

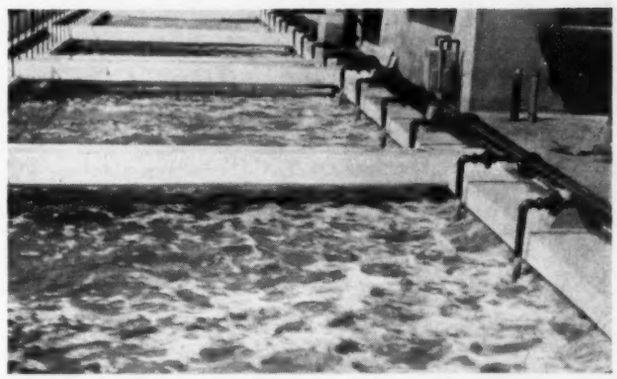


Plate 1—A Section of Aeration Tanks (Sewage Treatment Plant, Golden Gate Park, San Francisco), an Example of Uniform Diffusion

3. *Miscellaneous*: Very often protection from cement grout (or other material used to install plates), dirt, debris, etc., is not provided during installation or when tanks are empty, and appreciable surface clogging results. A plate cover (see sketch) should be used to shield plates from cementing materials during installation, and other protective measures should be observed when tanks are empty.

Air Side Clogging

1. *Dirt in Air*: Air containing a high quantity of soot or other impurities is a major source of clogging on the underside of diffuser plates or inside of diffuser tubes. Selection of effective air filters and care in locating the air intake are obvious preventatives.

The thought should be injected here that diffusers of higher permeability than the type used during the early days of sewage aeration are undoubtedly subject to less clogging of this nature because of relatively larger pores through which many of the fine suspended particles pass rather than stop. It is doubtful if the air bubbles released from higher permeability diffusers are very much larger than the bubbles discharged from the earlier low permeability grade of diffuser. The fact remains that higher permeability diffusers have not been less effective than those of lower ratings previously specified.

2. *Oil in Air*: Reciprocating compressors are now rarely used in sewage aeration, but the oil which they force through air lines is responsible for pronounced diffuser pore plugging. Fortunately, the low pressure required for sewage aeration permits the use of rotary blowers of the centrifugal or positive displacement type. If reciprocating units must be used for any reason, an oil trap or filter of some kind should be used between the compressors and the diffusers.

Certain types of primary air filters depend on the use of an oil for cleaning or renovating. In this operation it is recommended that a partial wash with a solvent be given after the oil treatment so that oil will not be blown free and carried through the diffusers.

3. *Air Pipe Rust or Scale*: It is generally recognized that cast iron pipe as a material for air lines is sufficiently resistant to corrosion from moisture to be considered to have almost an endless life. Genuine wrought iron is likewise considered satisfactory. Galvanized or sherardized steel pipe would be considered suitable for relative short periods of life, while ordinary black iron pipe or steel is not suitable.

In spite of the consideration given to this phase of air pipe design, there is evidence that some air side clogging is caused by iron oxide in the form of rust particles and scale.

There are economic considerations involved in preventing this source of clogging. Aluminum and copper pipe have been used

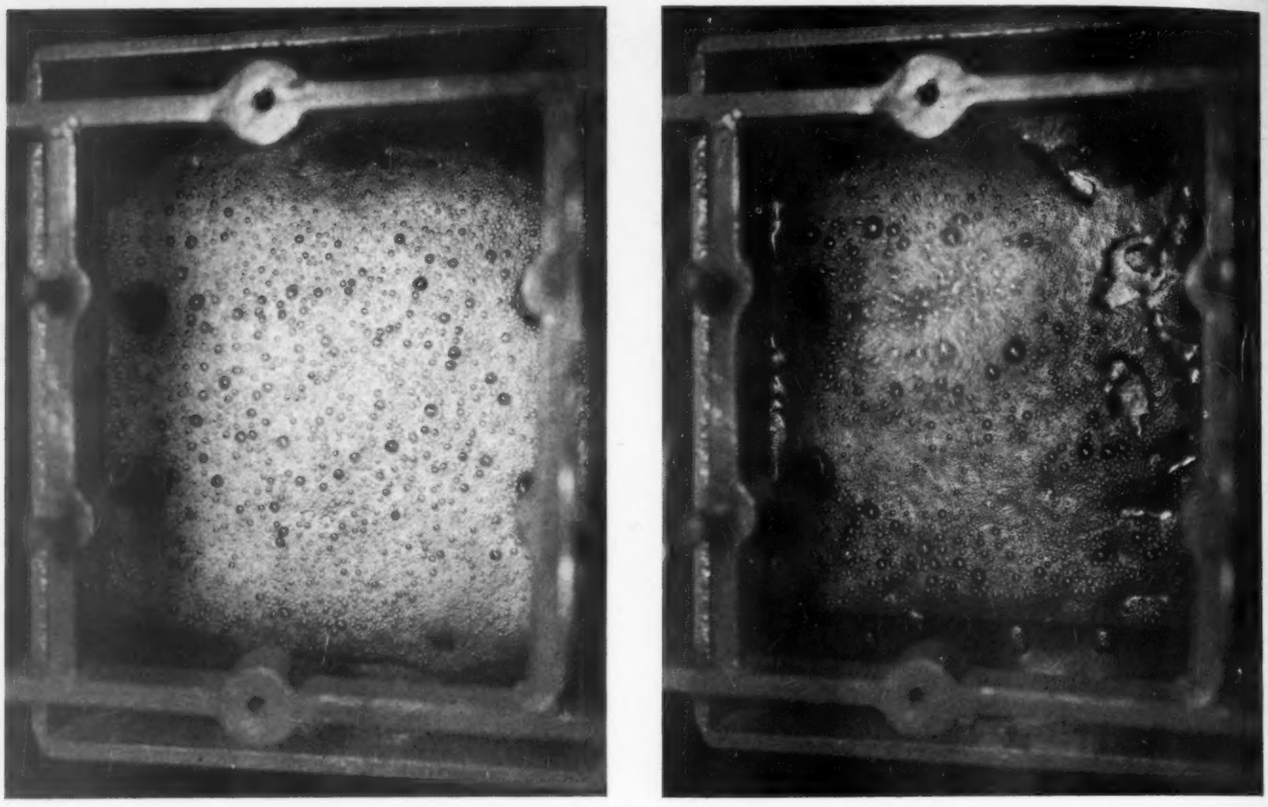


Plate 2—An Illustration of Good Uniformity of Diffusion on the Left; Poor Uniformity on the Right. (Photographs Taken Looking Down on Diffusion Plates in Testing Apparatus)

for the smaller air lines and are recommended along with other types of corrosion resistant pipe. However, if the use of such pipe raises the installation cost appreciably it should be balanced against the estimated cost of diffuser servicing and replacement.

4. *Miscellaneous*: Air lines left in a dirty condition after installation can cause clogging of considerable magnitude. The remedy is obvious. Cast iron diffuser plate containers may cause the same difficulty as does iron piping, but to a lesser degree. Mr. William M. Piatt has avoided this possible source of trouble in designing containers for some of his plants in North Carolina, by using aluminum container linings. At other plants the entire plate holder is to be of aluminum.

Restoration of Diffuser Efficiencies

Because of the diversified types and degrees of clogging experienced in the 100-odd activated sludge plants in the country, it is natural to expect that there are many methods of cleaning in use. Lacking information on the subject, plant superintendents and operators have, more or less successfully, devised and developed individual methods of their own.

Plate Cover for Protecting Diffuser Plates During Setting

The writer's company, in addition to considerable experimental work in the research laboratories. has fostered a survey among those in charge of plants throughout the United States and Canada, believing that many practical methods of diffuser cleansing would come to light. The response to our inquiries and the cooperation received has been most gratifying and has made it possible to present the outline to follow. Some of the methods have been improved, amplified or supplemented as the result of certain research work which we have conducted.

Methods employed in diffuser cleaning can be divided into two general classes; viz., methods applicable to diffusers in place (suitable largely to liquor side clogging) and methods which are adaptable only to removed diffusers. Tubes are cleaned for the most part by the latter method because they may be quickly and easily removed. The methods to follow are not given in an order to indicate preference.

Cleaning Diffusers in Place

1. *Caustic Treatment*: Clean aeration tank and surface of diffusers thoroughly with hose stream and leave about ½ in. of clean water over plates, providing the slowest practical air diffusion during this period. Dissolve about 1/10 lb. commercial lye crystals over each square foot of plate and then shut off air. Allow solution to penetrate plate (10 to 15 minutes), add more clean water, and then turn air on a maximum rate. (Note: This method is chiefly applicable to removal of organic compounds.)

2. *Sand Blasting*: Dry plates thoroughly by draining containers completely and blowing out porous structure with air

Plate 3—Diffuser Plates Stacked in Furnace for Burning-Out of Organic Matter. (More Clearance Between Plates Preferable; See Method 14)

applied at high rate. Sand blast plate surface with usual type of sand blast equipment, using "Blastite" Grain. Remove not more than 1/32 in. from surface, *maintaining maximum air discharge during the operation.* One minute or less is required to clean a plate by this method.

3. *Surface Spalling*: This method is applicable to diffuser plates of the silica type. Dry plates by draining containers and blowing out porous structure with air at high rate. Apply blow torch flame to entire top surface of plate until it cracks into flakes. Sweep off this film or scale and rub surface smooth with a Carborundum rubbing block. Sweep off particles again. Leave air on during entire operation.

4. *Burning Out Surface*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, saturate each plate with one quart of alcohol and apply heat with blow torch. Dry and brush off surface.

5. *Acid Washing and Scrubbing*: Dry plates by draining containers and blowing out porous structure with air at high rate. With air off, apply a 30 per cent solution of hydrochloric (muriatic) acid to the surface liberally and allow same to penetrate somewhat before turning on air at a low rate. Scrub with a stiff brush, using more acid if necessary. Follow with a clean water wash and scrubbing with a wire brush, continuing air discharge at a somewhat higher rate. (Note: This method is chiefly applicable to removal of inorganic compounds.)

6. *Vacuum Cleaning*: This method has not been proven but was suggested by authorities at the Milwaukee Sewage Treatment Plant, where a trial was intended. A vacuum pump was to have been used with a suction inlet of small area which would be held closely against and moved back and forth across the diffuser surface to be cleaned.

7. *Rest*: Dry plates by draining containers and blowing out porous structure with air at high rate. Allow diffusers to rest while dry for a week or more. (Note: The theory of this treatment is that the change of conditions will cause the bacterial and protozoa growth in the porous structure to die.)

8. *Chlorine Treatment*:* Introduce a strong dose of chlorine into the branch air line leading to each diffuser assembly for several minutes during a low rate of air flow. Following by blowing out diffusers with the maximum possible rate of air flow. (Note: This method is chiefly applicable to removal of organic compounds and carbonates.)

9. *Steam Backwashing*:* Dry diffusers by draining and blowing out porous structure with air at high rate. Introduce steam into the branch air line at 10 lbs. pressure and scrub diffuser surface simultaneously with a stiff brush.

10. *Water Backwashing*:* Introduce clean water into the branch air line under pressure of 15 to 20 lbs. per sq. in. Scrub diffuser surface simultaneously with a stiff brush.

Cleaning Removed Diffusers

11. *Acid Pickling*: Wash diffusers with water (use hose and brush). Set in a vertical position and allow to drain and dry as much as possible. Soak in 30 per cent solution of hydrochloric or nitric acid for four hours. Wash with water. (Note: Use Hydrochloric acid if it is desired to dissolve inorganic compounds and nitric acid if it is desired to oxidize organic compounds.)

12. *Caustic Treatment*: Place diffusers in vessel containing a 10 per cent solution of sodium hydroxide (lye) and boil for about one hour. Remove from this solution and wash thoroughly in boiling water. (Note: This method is only applicable to partial removal of organic compounds, chiefly fats, which are saponified by the caustic soda and then dissolved in hot water.)

13. *Sandblasting*: Dry diffusers thoroughly (preferably in an oven of some kind) and sandblast (Method 2) on either or both sides, as required. It is recommended that, where practicable, the diffuser be inserted in a container which will make it possible to force air through it at a high rate during the operation. This will eliminate any clogging by the dust created.

14. *Burning*: This method is applicable to diffusers of the fused crystalline alumina type. Place diffusers in a furnace or kiln in any convenient position, leaving a space of not less than ½ in. between units. Raise temperature gradually during 10 hours to about 1000 deg. Centigrade and then allow to cool gradually. The cycle should take at least 16 hours. Fuel of any kind is satisfactory, but care must be taken to avoid impingement of flame against diffuser surfaces. At Decatur, Ill., gas from sludge digestion was used.

Selection of Method

Every plant operates under conditions peculiar to itself, which will prove a factor in the ease or difficulty of diffuser servicing and the methods of cleaning which can be, or should be, used. One method may work satisfactorily in one place but be wholly unsatisfactory in another place or at another time.

In general, methods used on diffusers *in place* are not better than 75 per cent effective and range down to as low as 10 per cent where the clogging is almost wholly on the air side. Methods of cleaning removed diffusers are much more effective and are from 60 to 95 per cent effective. It is usually a combination of two or more methods which will produce the best result; because, any single method is not a cure-all.

The combination of causes and degree of clogging vary greatly and therefore it is not possible to give a rating of effectiveness to each method of restoration. It can be stated, however, that acid pickling of removed diffusers (Method 11) followed by burning in a furnace or kiln (Method 14) is 90 to 100 per cent effective, regardless of type or degree of pore plugging. This combination is therefore, recommended where serious clogging exists.

A simple improvised furnace can usually be built at a sewage plant to refire diffusers, other considerations being satisfactory. Where this work proves impracticable in the field, the writer's company will use its kilns at Niagara Falls for refiring when requested. Such arrangements would offer an added advantage in that refired diffusers can easily be retested and rated so that they may be properly re-installed thereafter.

The above suggests the consideration of providing a simple permeability testing apparatus at sewage treatment plants which would be useful in re-rating removed diffusers which have been cleaned at the plant. Even though original markings are retained, which is doubtful, all units will not respond equally to the cleaning method employed and will have a new permeability rating which should be determined when re-installation is made.

For acid pickling (Method 11) a wooden tub is satisfactory. The caustic treatment requires an iron kettle because of the boiling operation. Workmen should use precaution in these methods by wearing rubber gloves, aprons, etc. Tongs can be used to handle diffusers.

Where existing plate containers do not permit simple mechanical plate removal, a joint composed of sand in the bottom ½ in. and cement grout in the top, is recommended for setting plates in holders. This will save time and avoid plate breakage when removal becomes necessary. Plates so installed should be set with a lime mortar under the supporting edges to insure an even bearing.

Conclusion

The practice of regular servicing should be stressed if the diffusers in any plant are subject to a known source of clogging. If this is done, whether it is apparently needed or not, the permeability will be maintained indefinitely, in all probability, and one or more of the simple and least costly methods of revivification can be employed.

Because of the several potential sources of diffuser pore plugging which exist, and because many of these cause air side clogging, the use of plate containers which permit easy removal of plates is recommended. Ease of removal and replacement is one of the important advantages of diffuser *tubes* for smaller plants.

Diffusers of high permeability are less subject to clogging because of larger pores. They operate on a slightly lower air pressure than low permeability diffusers. Because of these advantages, and the fact that effectiveness of aeration is not decreased (compared to that provided by low permeability diffusers), plates of a higher rating are recommended.

*Methods applicable to tubes or plates and of some benefit also in cleansing the air size of diffusers.

PRACTICAL ASPECTS OF STORING AND HANDLING FERRIC CHLORIDE[1]

By J. M. POTTER*

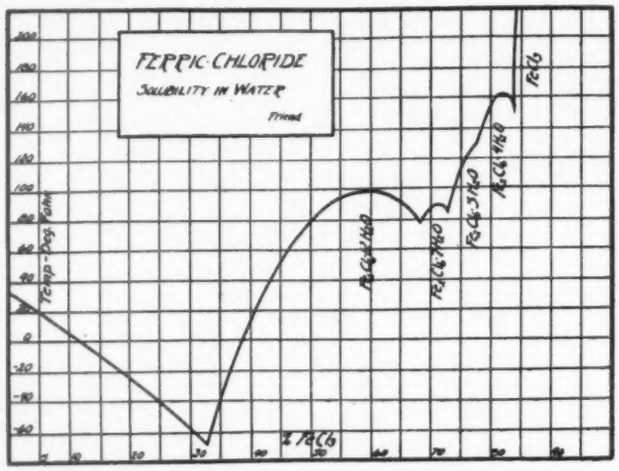
Philadelphia, Pa.

The steady advance in the utilization of chemicals in sewage treatment has created an increasing interest among engineers and municipal officials in the problems involved in their use.

The object of this article is to supply a concise outline of the more significant properties of ferric chloride and effective methods of handling and storing it.

At this time there are three commercial forms of ferric chloride available:

1. *Liquor*—An aqueous solution which is prepared to contain between 39 and 45 per cent $FeCl_3$ by weight to meet exact specifications.
2. *Crystals*—A definite crystal of the formula $FeCl_3.6H_2O$ containing 60 per cent $FeCl_3$ by weight.



Solubility of Ferric Chloride at Varying Temperatures. Note that a 45 Per Cent Solution will Crystallize at About 52 Degrees F.; a 33 Per Cent at Zero.

3. *Anhydrous*—A complete water-free form containing 98 per cent or more $FeCl_3$ by weight.

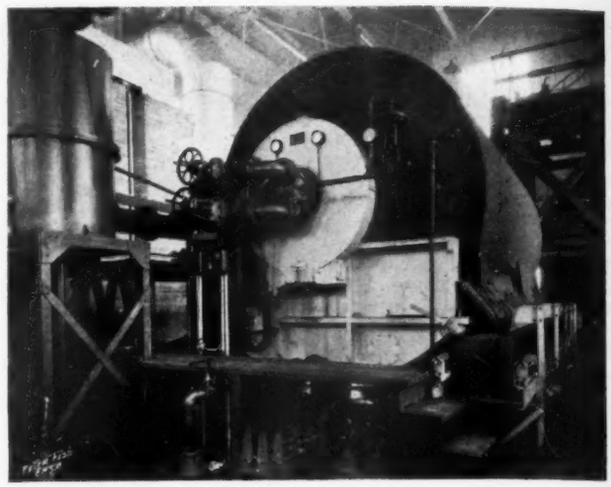
Liquid Ferric Chloride

Commercial ferric chloride liquor is a dark brown, somewhat oily appearing aqueous solution of varying concentrations. Obviously for the lowest transportation cost, the $FeCl_3$ content of these solutions should be as high as possible but concentrations are limited by crystallizing temperature conditions during transit or storage. To prevent crystallization the strength of solutions usually varies from 45 per cent in midsummer to 39 per cent $FeCl_3$ in midwinter. Average concentration of shipments over a period of several years has been 42 per cent.

Shipments are made in rubber-lined tank cars holding 8,000 gallons and averaging 40,000 pounds of dissolved $FeCl_3$ per car. The dome of the tank car is equipped with sump and center level discharges, a filling and air pressure pipe with gauge connection and a rubber disk safety valve which relieves at gauge pressures exceeding 25 pounds. The car is unloaded by attaching a rubber hose to the discharge connection and siphoning in case of low level storage tanks or by applying air pressure up to 25 pounds where a lift is required.

The maximum lift by air ejection is limited to 40 feet. If higher lifts are necessary a suitable pump should be provided.

Ferric chloride liquor (referred to in the trade as liquid ferric chloride) is easily handled and is usually the most economical form for use by the large consumer, who is reasonably near a source of supply. However, it has the disadvantage of requiring transportation costs on its 58 per cent (average) water content, railroad siding facilities, and storage tanks for one or more cars.

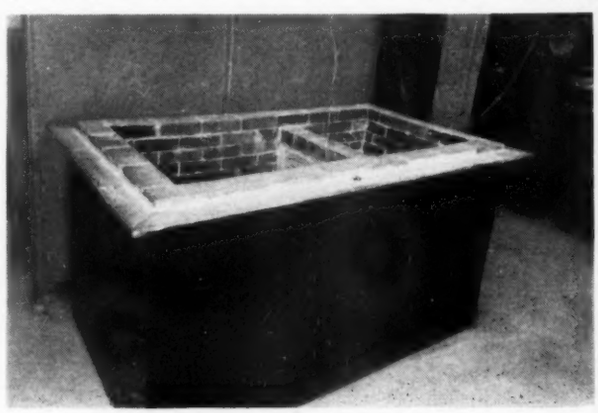


Filter and Sludge Conditioning Tank—Chicago Sanitary District. Here the Operations are Under the Control of an "Electric-eye".

Storage Tanks

Except for its strongly corrosive nature, ferric chloride liquor offers no storage hazard, the only storage problem being provision of sufficiently large ferric chloride resistant tanks to store one or more carloads. *Ten thousand gallons should be the minimum storage capacity for plants using tank cars of ferric chloride.* Wood, reinforced concrete, or steel tanks lined with rubber with all exposed exterior surfaces painted with a ferric chloride resistant paint are the ideal containers. Covered tanks need not be sheltered but, in the case of unsheltered tanks, the strong liquor received during warm weather should be diluted in the storage tanks during the colder months to prevent crystallization. If possible, storage tanks should be elevated to permit the liquor to flow by gravity to dilution tanks or feeders, thereby confining all pumping to the simple air lift unloading operation from the car.

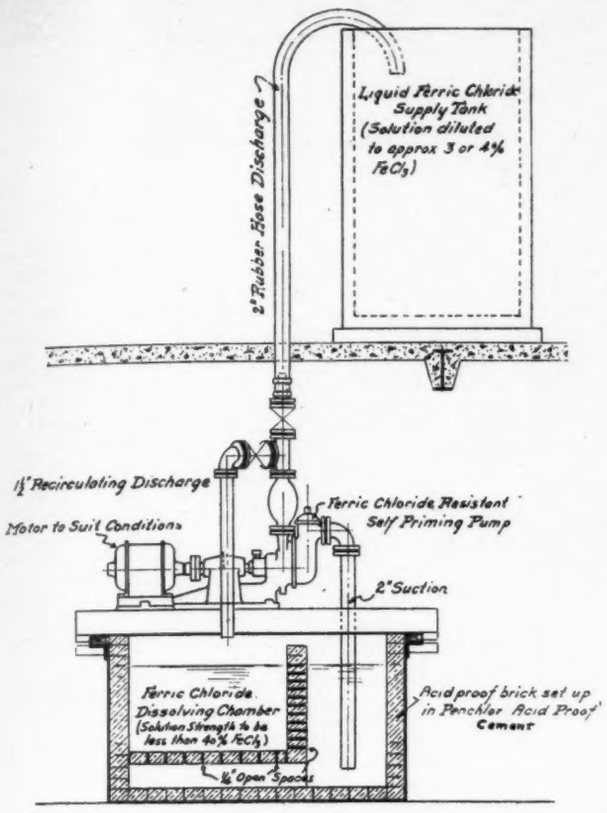
The concentrated ferric chloride solution taken from storage is preferably diluted to a 2 or 3 per cent solution when applied



Ferric Chloride Dissolving Tank—Hagerstown, Md. Sewage Treatment Works. Steel Tank with Rubber Lining and Faced with Acid-proof Protecting Brick Laid with Acid-proof Cement. Anhydrous Ferric Chloride in Non-returnable Steel Drums Stocked in Rear.

*Chemical Engineer, Technical Service Dept., Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.

[1]From WATER WORKS AND SEWERAGE, January, 1935.


2" Rubber Hose Discharge
Liquid Ferric Chloride Supply Tank (Solution diluted to approx 3 or 4% FeCl3)
1½" Recirculating Discharge
Motor to Suit Conditions
Ferric Chloride Resistant Self Priming Pump
2" Suction
Ferric Chloride Dissolving Chamber (Solution Strength to be less than 40% FeCl3)
Acid proof brick set up in Perchlor Acid Proof Cement
½" Open Spaces

TYPICAL ARRANGEMENT of ANHYDROUS FERRIC CHLORIDE MIXING AND PUMPING UNIT

Sketch of Trouble Free Equipment and Method of Dissolving, Diluting and Feeding Ferric Chloride.

by one of the methods noted later in this article under "Feeding Equipment." Rubber-lined wood tanks under cover serve the Sewage Treatment Works of Milwaukee.

Crystal Ferric Chloride

Crystal ferric chloride is the oldest commercial form. As indicated in the accompanying graph, four hydrated crystals of ferric chloride can be formed; but, only the dodecahydrate, $Fe_2Cl_6.12H_2O$, (commonly written $FeCl_3.6H_2O$) is now commercially available. This material contains 60 per cent $FeCl_3$ by weight, is in the form of large yellow or brown lumps, has a melting point of 98.6° F., is slowly soluble in water at average tap temperatures, and is moderately hygroscopic.

The crystals are marketed in non-returnable, hardwood, paraffine-lined barrels of 55 gallons' capacity, which contain approximately 435 pounds of material. To prevent melting, and possible leakage, it is advisable to store barrels in single tiers under dry conditions at temperatures below 98.6° F. *The storage space required is approximately 70 square feet per ton of $FeCl_3$.*

Equipment for preparation of solutions and feeding crystal ferric chloride will be discussed in connection with anhydrous ferric chloride solutions, because of the close similarity of each.

Anhydrous Ferric Chloride

Anhydrous ferric chloride occurs rarely in nature, possibly the only source being the lava of Vesuvius. It takes the form of small greenish-black crystals with a melting point of 577.4° F., and is extremely hygroscopic, being readily soluble in water to 45 per cent concentrations at room temperatures above 55 degrees.

At present, the anhydrous form is being shipped in non-returnable steel drums holding 150 pounds of material. The drums, 15½ inches in diameter by 20 in height and weighing 10 pounds, are fitted with a 9-inch air-tight gasket and lid held in place by 4 screw bolts. These drums are convenient packages which may be stacked and stored indefinitely without deterioration. *Storage space required is approximately 40 cubic feet per ton of $FeCl_3$.*

Anhydrous ferric chloride has a decided advantage over the other forms by reducing transportation costs and storage space requirements 40 per cent or more. In addition, waste by leakage or deterioration is eliminated.

Preparation of Solution, Feed Methods And Equipment

The hygroscopic character of ferric chloride prohibits the use of dry feeds. The corrosive nature of solutions prevents the use of ordinary piping and feeding equipment. A 20 per cent ferric chloride solution rapidly attacks the common metals and dehydrates wood, causing it to warp and shrink. Wood, or reinforced concrete, resists the action of weak solutions since excessive hydrolysis forms a protective hydrate coating. Equipment made of, or lined with, rubber, glass, Bakelite, or ceramic material, or the resistant metals such as Durichlor, or Hastelloy "C," will resist all concentrations of ferric chloride at normal temperatures. Rubber, glass, or ceramic materials may require additional protection against mechanical abrasion, or heat variation.

Feeding apparatus may vary from a simple solution tank with constant head orifice box to a modern "electric eye" controlled installation such as that used at the Chicago Sanitary District. The ideal and foolproof method of feeding involves 3 distinct steps: (1) Solution, (2) Dilution, (3) Application.

Dissolving Tanks

Solution tanks are necessary for dissolving either the crystal or anhydrous ferric chloride. Concentrations of less than 40 per cent are recommended to prevent crystallization and, in the case of anhydrous ferric chloride, high temperatures at the time of preparing the strong solution.

Solution strengths should be determined by adding a weighed quantity of ferric chloride to a definite volume of water as hydrometer measurements have proved to be unreliable. The tank should be at least partly filled with water before adding anhydrous ferric chloride to prevent the formation of the slowly soluble higher crystals and if the total contents of a drum are not added at one time the lid should be tightly replaced. Solution tanks of steel, reinforced concrete, or wood, lined with rubber and faced with acid-proof brick and cement, and of sufficient size to dissolve a 12 hour supply of ferric chloride, are preferable. A material rack, or compartment, and mechanical means of agitation are desirable features. Here illustrated is such a tank in connection with a pump which serves the dual purpose of agitating and lifting the concentrated liquor to the dilution tank above. A similar tank is in use at Hagerstown, Md., where the solution is raised to the dilution tank by a vacuum lift.

Ferric Chloride Service Tank—Rubber Lined. Note Hose Connections and the "Saunders" Pinch-type Diaphragm Valves for Corrosive Liquids. Dearborn, Mich., Sewage Treatment Works.

Dilution Tanks

Dilution tanks are advisable for preparing and supplying uniform solutions to feeders. Concentrated solutions are diluted to 3 or 4 per cent $FeCl_3$ by adding gauged volumes of water and liquor. Experience indicates that stronger than 5 per cent solutions exhibit intense localized reaction on application and solutions weaker than 2 per cent may be appreciably hydrolyzed, especially by diluting waters of high alkalinity. Dilution tanks may be similar in construction to solution tanks without the acid-proof brick facing. Reinforced concrete tanks painted with a ferric chloride resistant paint, or large stoneware crocks are suitable. Other desirable features would include a mechanical stirrer, a graduated gauge rod, or glass, and a capacity for at least 4 hours' supply of solution. A tank with the depth exceeding other dimensions is preferable for more accurate gauging.

Solution Feeder

A positive displacement or a variable siphon head type of solution feeder is recommended for applying ferric chloride solutions. Several such corrosion resistant feeders, which have entirely corrected the uncertain performance peculiar to the old orifice type feeder, are on the market today. These feeders may be either manually or automatically regulated. Space does not permit even a limited discussion of all such feeders but following is a list of manufacturers: Builders Iron Foundry, Providence, Rhode Island; Galigher Company, Salt Lake City, Utah; Hills-McCanna Co., New York City; Omega Machine Co., Kansas City, Mo.; Phipps & Bird, Inc., Richmond, Va.; Wallace & Tiernan, Inc., Newark, N. J.

Obviously, a gravity flow from solution tank to the final point of application is the ideal feeding arrangement. When lifting is necessary, any method which employs ferric chloride resistant materials may be used. Rubber-lined or hard rubber pumps, pipe and fittings are satisfactory for handling ferric chloride solutions at normal temperatures. Equipment made of Durichlor, or Hastelloy "C" is recommended for hot solutions.

For simple coagulation of sewages with ferric chloride, water purification practice for flocculation and sedimentation will give the best results. For sludge conditioning rapid agitation for 5 or 6 minutes followed by continuous filtration is preferable to the batch method.

MENSURATION*

Calculating Areas, Volumes, Surfaces

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a commont point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

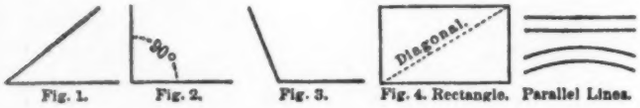


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

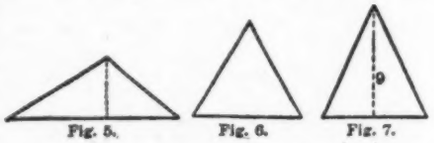


Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

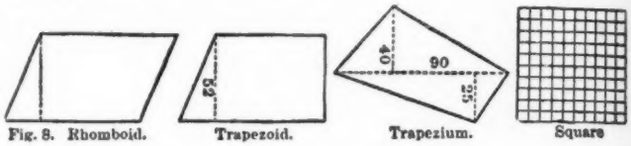


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A trapezoid is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

*Reproduced from "Rapp's Calculator," published by C. Rapp & Sons, Chicago, Ill.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A trapezium is a quadrilateral having none of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A rightangled triangle has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

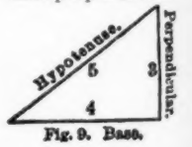


Fig. 9. Base.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle — illustrated by Fig. 10—we derive the following rules.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

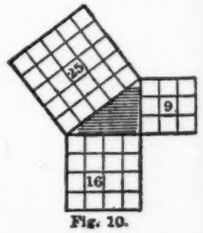


Fig. 10.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base)=16; of 3 (perpendicular)=9; the square root of their sum (25)=5, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a tringular field whose hipotenuse is 75 rods, base 60 rods?

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Answer—45 rods.

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be ($\sqrt{4000} = 63.246$) 63¼ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000 +$

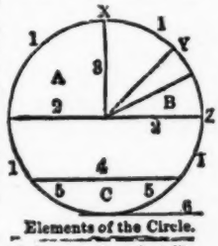
To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

What is the diagonal of a field 35 rods square?

This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

$35 \times 10 = 350$,
1% of $350 = 3.5$
7)346.5
Ans. (rd.) 49.5

A circle is a plane figure bounded by a curved line, (1, 1, 1, 1) called circumference, every point of which is equally distant from the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the circumference of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—$28 \times 3\,1/7 = 88$ in.

To find the diameter of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—$144.5 \times 3183 = 46$ in.

To find the area of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—$20^2 \times .7854 = 314.16$ sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—$50^2 \times 3.1416 = 7854$ sq. ft.

To find the radius of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, $43560 \times .3183 = 13865$; $\sqrt{13865} = 117\frac{3}{4}$ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the area of a sector of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.

The diameter of a log is 24 inches; how large a sill can be cut from it?

$24 \times .707 = 17$ in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—$12 \times 1.414 = 17$ in.

To find the area between the two concentric circles. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.

Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—$20 \times 80 = 1600 \times .7854 = 1256.64$ sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—$50 \times .464 = 23.2$ in.

An ellipse is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an eclipse whose diameters are .41 and 29 ft.

$(41 + 29) = 70 \times 3.1416 \div 2 = 110$ ft. nearly.

To find the area of an eclipse. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

$60 \times 40 = 2400 \times .7854 = 1885$ sq. ft. nearly.

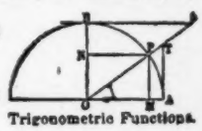
Triangle. Square. Pentagon. Hexagon. Octagon.

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.

Find sq. in. in each.

$30^2 \times 433 = 389.7$ in. T; $10^2 \times 4.824 = 482.84$ in. O.



Trigonometric Functions.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

P M, sine.
O M, cosine.
A T, tangent.
B S, cotangent.
O T, secant.
O S, cosecant.
M A, versed sine.
B N, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A cube is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Find sq. in. in surface of a 12 in. cube.

Answer—$12^2 \times 6 = 864$.

How many cubic in. in a cubic foot?

Answer—$*12^3 = 1728$.

Cube.

Find cu. ft. in a cu. mile.

Answer—$5280^3 = 147197952000$.

A parallelopiped is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—$10\frac{1}{2} \times 3 \times 1\frac{1}{4} = 39\frac{3}{8}$.

A prism is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

$10^2 \times .433 \times 2 = 86.6$ sq. in. in area of the two ends.

$10 \times 25 \times 3 = 750$ sq. in. area of sides. $86.0 + 750 = 836.6$.

Prism.

How many cubic inches in above prism, 10 by 25 inches?

Answer—$10^2 \times .433 = 43.3 \times 25 = 1082\frac{1}{2}$ cu. in.

A globe or sphere is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

Globe.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

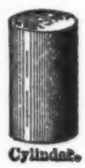
A cylinder is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.


Cylinder.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A cone is a solid, which has a circular base and tapers uniformly to a point called vertex.

A pyramid is a solid, resembling a cone, having three or more triangular sides.

To find the area of a cone or pyramid. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Cone.

Pyramid.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78\,54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The frustum of a cone or pyramid is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Find the area of a frustum of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Frustums.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the volume of any frustum. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$
$15^2 = 225$
$12 \times 15 = 180$

$183 \times .7854 = 143.73$ sq. ft., area of av. base of Fr. of cone.

3)549(183, area of av. base of F. of sq. pyr.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\,7/12$ sq. in., area of average base; $12\,7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\,7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A spheroid or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A cylindrical ring is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness, by square of thickness, and product by 2.467.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

Ring.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of greatest cube that can be inscribed in a given globe. Rule—Multiply the diameter of the globe by .577.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

CONVERSION FACTORS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc.. respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

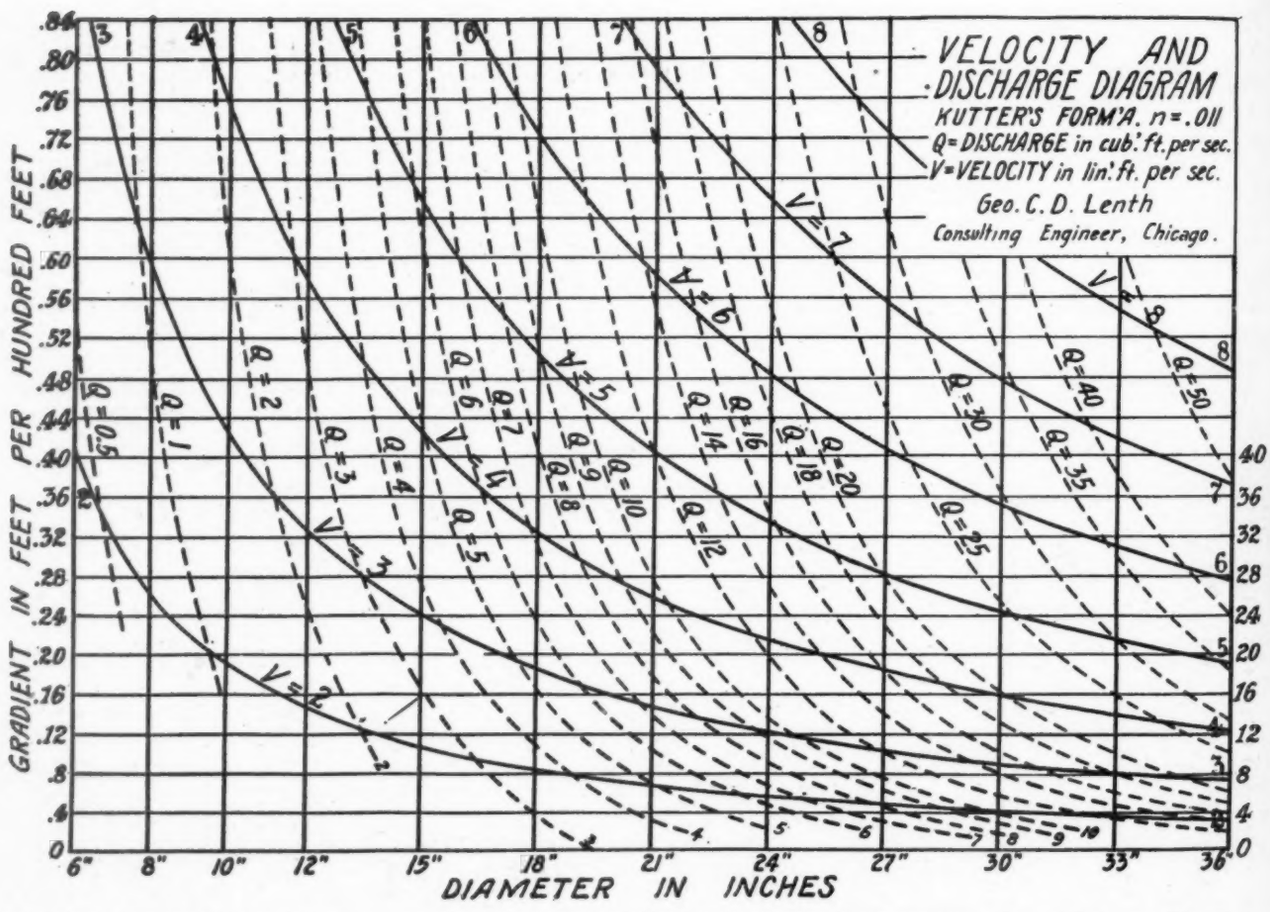
*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe

(Courtesy, Clay Products Assn.)


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORM'A. n=.011
Q=DISCHARGE in cub. ft. per sec.
V=VELOCITY in lin. ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

(Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure 0.20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.4 at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.)

RICHMOND • LOUISVILLE • OLD HICKORY • NEW BRUNSWICK

. . . and now TOPEKA

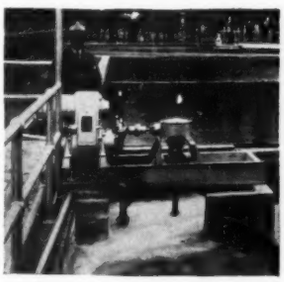
TYPICAL SAVINGS

Richmond, Va.
39% less alum
50% less wash water

Louisville, Ky.
20-30% less alum
30% less wash water

Old Hickory, Tenn.
23.5% less alum

New Brunswick, N. J.
27.2% less alum
11.2% less lime
27.2% less wash water



Dorrco Turbo Mixer at Topeka

report with DORRCO • FLOCCULATORS

$3,870 saved in one year through reduced consumption of softening chemicals (exclusive of alum) and the use of less blow down and wash water on the filters. That's why Topeka, Kansas, considers its Dorr installation of Turbo Mixers, Flocculators and Clarifiers a sound, self-liquidating investment for softening about 5.25 M. G. D. of domestic water.

Lime and soda savings aggregated $2479 per year—blow down and wash water $1391. Comparisons are made on a 12 month basis—in 1935 before the Dorr installation and in 1936, afterwards.

Topeka is but one of 92 successful Dorr installations that are paying for themselves out of chemical and other savings. Typical results from a few other cities appear at the left.

Let a Dorr engineer point the way to similar savings in your own plant.

TOPEKA, KANSAS OPERATING DATA*

	Before—12 mo.	*After—12 mo.*	*Saving*
Lime—grains/gal.	9.681	9.408	2.82%
Soda—grains/gal.	.248	.184	25.80%
Wash Water—% total flow	1.880	1.070	43.00%
Blow down—% total flow	1.930	1.180	39.00%
Total chemical cost (incl. alum) per M. G.	$13.59	$11.23	$2.36

DORRCO

*Courtesy of Mr. Lloyd B. Smith, Commissioner Water Works, and Mr. Daniel H. Rupp, Water Production Engineer, Topeka.

THE DORR COMPANY INC.

ENGINEERS • 570 Lexington Ave., New York

CHICAGO • LOS ANGELES • TORONTO • DENVER • ATLANTA

DORR TECHNICAL SERVICES AND EQUIPMENT ARE AVAILABLE FROM THE FOLLOWING COMPANIES:

HOLLAND: Dorr-Oliver N. V. The Hague
FRANCE: Soc. Dorr-Oliver, Paris
GERMANY: Dorr Gesellschaft, m. b. H. Berlin
ENGLAND: Dorr-Oliver Company Ltd., London
AUSTRALIA: Crossle & Duff Pty. Ltd., Melbourne
SOUTH AFRICA: Edward L. Bateman Pty. Ltd., Johannesburg
JAPAN: Andrews & George Co. Inc., Tokio
ARGENTINA: Luis Fiore, Buenos Aires
BRAZIL: Oscar Taves & Co., Rio de Janeiro

THE TRAIL OF PROGRESS *leads to* BUFFALO

JUST as the parade of advancing civilization leads toward more comfortable and healthful living conditions, so does progress in purification methods advance the aim toward a pure, safe water supply.

Twenty years ago, when Buffalo purchased its first W&T Chlorinator, the art of Chlorination was in its infancy, chlorine control equipment was by today's standards, crude, and inefficient. Today, Chlorination is recognized as the everyday need of every water supply —and Buffalo, in common with thousands of other American municipalities, controls its application efficiently, dependably and economically with W & T Visible Vacuum Chlorinators. And so goes the trend of Chlorination — yesterday's obsolete, pressure type Chlorinator gives way to today's Visible Vacuum — yesterday's methods of manual control become today's automatic operation — leading always toward more rigid control of the Chlorination process.

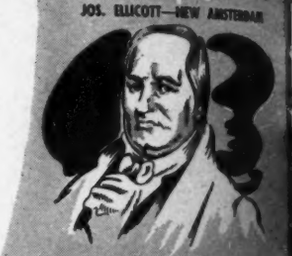
Whatever your water works problem may be, you will find information and help, together with a pleasant social time, in Buffalo at the A. W. W. A. Convention, June 7th to 11th. The W & T "At Home" sign will be out in Booth Nos. 52, 53, 54 and 55. Let us show you the new types of W & T equipment and welcome you there. *"The Only Safe Water is a Sterilized Water."*

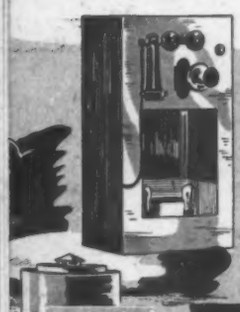
WALLACE & TIERNAN COMPANY, Inc.

Manufacturers of Chlorine and Ammonia Control Apparatus

NEWARK, NEW JERSEY -:- BRANCHES IN PRINCIPAL CITIES

★ *Chlorinators for Water Works—Sewage Plants—Swimming Pools—Industrial Plants.*





1. One of these three ble Vacuum Chlo tors—from the Rotor. ing as little as .03 po of chlorine per day.

2. The Equiscale, feeding .5 to 12 pounds per day.

3. To the Master Chlorinator, fe as much as 2000 pounds per day be adapted to either manual, semi- matic control, i. e. automatic start stop or complete automatic proporti chlorine dosage.